GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

For the Year 1902.

TRENTON, N. J.:
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HIS EXCELLENCY FRANKLIN MURPHY, Governor, and
ex-officio President of the Board.................... TRENTON.

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JOHN C. SMOCK .... TRENTON.

I. Congressional District.

CLEMENT H. SINNICKSON* .... SALEM.
VACANCY ....

II. Congressional District.

EDWARD C. STOKES .... MILLVILLE.
EMMOR ROBERTS .... MOORESTOWN.

III. Congressional District.

HENRY S. LITTLE† .... MATAWAN.
M. D. VALENTINE .... WOODBRIDGE.

IV. Congressional District.

WASHINGTON A. ROEBLING .... TRENTON.
WILLIAM J. TAYLOR‡ .... HIGH BRIDGE.

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FREDERICK A. CANFIELD .... DOVER.
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VI. Congressional District.

GEORGE W. WHEELER .... HACKENSACK.
WILLIAM F. HALL .... POMPTON LAKES.

VII. Congressional District.

WENDELL P. GARRISON .... ORANGE.
HERBERT M. LLOYD .... MONTCLAIR.

* Mr. Sinnickson resigned December 2d, 1902.
† Mr. Little resigned February 25th, 1903.
‡ Mr. Taylor died February 17th, 1903.

VIII. Congressional District.

FREDERIC W. STEVENS ....NEWARK.
HARRISON VAN DUYNE ....NEWARK.

IX. Congressional District.

JOSEPH D. BEDLE ....JERSEY CITY.
VACANCY* ....

X. Congressional District.

S. BAYARD DOD ....HOBOKEN.
VACANCY ....

* Mr. George E. Tennant elected to fill this vacancy February 25th, 1903.

To His Excellency Franklin Murphy, Governor of the State of New Jersey and, ex-officio, President of the Board of Managers of the Geological Survey.

SIR—I have the honor to submit my Annual Report upon the work of the Geological Survey for the year 1902.

Yours respectfully,

HENRY B. KÜMMEL,

State Geologist.

TRENTON, N. J., November 29th, 1902.

ADMINISTRATIVE REPORT.

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Administrative Report.

Henry B. Kümmel, State Geologist.

At a meeting of the Board of Managers of the Geological Survey, held January 10th, 1902, the position of State Geologist, made vacant July 1st, 1901, by the resignation of Dr. John C. Smock, was filled by the appointment of Henry B. Kümmel, who had been Acting State Geologist *ad interim*.

A summary of the work of the Survey for the year ending October 31st, 1902, is herewith presented in the Administrative Report, together with certain recommendations which seem to be demanded by the results of investigations. Some of the results of special studies for the year are presented in the accompanying papers.

Administrative work has of necessity taken a large part of the time and attention of the State Geologist. The Survey is in frequent receipt of letters requesting information of one sort or another relating to the resources of the State. In many instances a careful answer necessitates considerable investigation on the part of the State Geologist, either in the reports of the Survey or in the unpublished data. Many of them relate to underground water-supplies and the depth at which water may be obtained. Others concern deposits of peat, clay, cement, rock, &c. In many cases samples are submitted for examination. All such letters are carefully answered and, so far as possible, the desired information is furnished, for it is recognized that this is one of the most important functions of the Survey.

The scientific work of the State Geologist during the year has been varied. In January the iron and copper mines of the State were visited and examined in detail. In the spring some work was done with Professor Salisbury upon the Glacial Geology of Bergen and Passaic counties. In July a short time was spent

with Drs. Van Hise and Wolff, of the United States Geological Survey, examining the peculiar problems about Franklin Furnace. Most of the field season, however, was spent in work upon the clay deposits, a part of the time in company with Dr. Ries. In the course of this investigation, all the worked clay deposits of the State were examined, samples collected, factories visited and a detailed map of the Woodbridge clay district partly prepared. Many undeveloped clay properties were also prospected. In this work the detailed information collected by Mr. Knapp, in his work upon the surface deposits, was of great assistance.

The scientific work in the office has been of a varied character. Papers upon the Geology of the Green Pond Mountain Region and upon the Mining Industry were prepared, as well as the Administrative Report for the Annual Report for 1901. The other papers in the report were read in manuscript, and afterwards the entire report read twice in proof, and indexed. Later in the year, Volume V., the Report on Glacial Geology, now in press, was read, first in manuscript, then twice in proof. Some assistance was also given Mr. Salisbury in the preparation of maps to accompany the report. Editorial work on Forestry Bulletins I., II. and III. also demanded some attention. Comparatively little time has been afforded for study of any problems except those immediately in hand.

TOPOGRAPHIC WORK.

Mr. C. C. Vermeule has continued in charge of the topographic and draughting work of the Survey. He has been assisted by Mr. P. D. Staats in the field and Mr. Wm. A. Coriell in the office, but only a portion of their time has been given to Survey work.

The field work has included the completion of the survey of the region about South River and Matawan, which is to serve as a base for a detailed map of the clay deposits. During the last three months of the year Mr. Staats has been engaged in resurveying the northern portion of Sheet No. 7, in Bergen and Passaic counties, a region in which there have been great changes since the original survey in 1887. During the year about 252 square miles have been resurveyed, making a total of 1,515 square miles, or one-fifth the area of the State, now resurveyed, all of which is available for the large scale maps.

In the office, the Trenton and Shark River sheets were completed and the base for the clay map, embracing portions of the New Brunswick, South River and Matawan sheets, was drawn. This work covered about 218 square miles of land surface.

During the year, the Morristown, Atlantic City and Trenton sheets were published, and a new edition of Sheet No. 9 of the old series was issued. The following summary indicates the progress of the work upon the new sheets to date:

Sheets published, 16.

Sheets surveyed and drawn, but not published, 2.

Sheets surveyed, but not completely drawn, 5 (in part).

In addition to work upon the new series of maps, the preparation of illustrations for the Annual Report for 1901 and for Volume V. on Glacial Geology demanded much time.

SURFACE GEOLOGY.

The work on the Surface Geology has continued under the charge of Professor R. D. Salisbury, assisted by Messrs. H. B. Kümmel, G. N. Knapp and C. E. Peet. Mr. Salisbury has been engaged chiefly in completing the manuscript of his report upon the Glacial Geology of the State and in reading the proof sheets. A few days were spent in field work, viewing critical areas. Mr. Peet was engaged in compiling data regarding the glacial deposits of Bergen and Passaic counties, and has completed this work.

Mr. Knapp has been engaged continuously (except during January and a part of March) in field work in southern New Jersey and in office work. The most important scientific problems before the Survey, not only in their bearing upon the geological history of the State, but upon that of the entire Atlantic Coastal plain, are involved in the correct interpretation of the Pleistocene or Surface deposits of South Jersey and their relation to the underlying and older formations. These problems reach a complexity in this State which renders their study extremely interesting, but at the same time extremely difficult. The only hope of finally solving them correctly lies in most detailed and painstaking work, in the course of which all natural and artificial sections are studied, all well data collected and frequent borings made with a hand-auger. Mr. Knapp's work has been of this painstaking character,

and, although of necessity proceeding slowly, has been prolific of valuable results. In connection with this work, much information regarding the occurrence of workable clay deposits has been obtained.

The work of the State Geologist in this division has already been noted.

PALEONTOLOGY.

During November and December of 1901, and from July 1st to the close of the year, Dr. Stuart Weller has been engaged in the study and description of the Paleozoic fossils collected during previous years in the northern part of the State. This work has involved the examination of several thousand specimens, the description of several hundred forms, many of which were new to science, and the preparation of fifty-three plates of drawings. In the drawing he has been assisted by Miss Mildred L. Marvin, Miss Annie L. Weller and Mr. D. F. Higgins. His report has been received and will be published as an Appendix to accompany this report.

In March an arrangement was made with Dr. Charles E. Eastman, of the Museum of Comparative Zoology at Cambridge, Mass., to examine and classify the collection of fossil fish obtained at Boonton. This work is being carried on as rapidly as Dr. Eastman's many other studies permit.

CLAY AND CLAY INDUSTRIES.

In September, 1901, Dr. Heinrich Ries, who is a recognized authority on clays, both in this country and abroad, began the preparation of a report upon the economic and technical phases of the Clay Industry of the State. The importance of such a report can be judged from the fact that the annual value of manufactured clay products of the State is over $11,000,000, and that the value of raw clay mined and sold to manufacturers is about $500,000 more.

The report will contain chapters on the following topics: The Origin of Clay—Its Mineralogical and Chemical Composition—Its Physical and Chemical Properties and Their Effects; Prospecting for Clay; Mining Clay; The Technology of the Clay-

Working Industries; The Manufacture of Brick, Terra Cotta, Tile, Conduits, &c.; The Manufacture of Pottery; The Manufacture of Fire-Brick, &c.; New Jersey Clays—Their Geographical Distribution—Their Geological Distribution—Their Physical and Chemical Character—Their Availability and Use; Results of Physical and Chemical Analyses; Tests of Fire Brick and Crushing Tests of Brick. It is planned to include in the report maps showing (*a*) the general occurrence of clay and clay-working industries throughout the State; (*b*) the position of geological formations important as clay-bearing horizons; (*c*) a detailed map of the Woodbridge-Amboy clay district; (*d*) small maps showing the location of clay-beds in selected areas.

Considerable progress has been made in the preparation of this report. Much of the field work has already been done and many of the clay-working establishments have been visited. A large number of samples of raw clay have been collected, and considerable progress has been made in testing these. Not only have samples been taken from localities now being worked, but much prospecting has been done in the hope of aiding the development of new regions. Letters were sent to the newspapers of the State, calling attention to this work and requesting information from owners of undeveloped clay deposits. Numerous answers have been received and much information gained thereby. As many of these localities, as seem promising, will be examined by the Survey and samples of the clay tested.

The manufacture of fire-brick is one of the most important phases of the clay industry in the State. With a view of determining the relation between the chemical composition and the infusibility of fire-brick, samples have been obtained from the manufacturers of the State. These will be analyzed chemically, fused and the results tabulated and published, but without the name of the manufacturer. A report, however, will be rendered each manufacturer regarding the results of his own brick. It is hoped that by these tests, valuable data may be obtained regarding the chemical composition necessary to withstand a given degree of heat.

A series of tests to determine the crushing and breaking strength of common brick, and to afford a comparison of brick made by different processes from the same clay, and of different clays by the same process, has been undertaken. This phase of the work has been in charge of Professor I. C. Woolson, of Columbia University.

It is, of course, impossible to set a date for the completion of this work. It is hoped, however, that the report will be ready for the printer in May or June of the coming year.

ARTESIAN WELLS.

Mr. Lewis Woolman has continued to collect data concerning the artesian wells in the State, particularly in the southern portion, and in part presents a record of the more important of the deep wells drilled during the year. Attention is called particularly to the records of the wells at Hammonton and Cape May. Mr. Woolman's tentative conclusion that the water horizon found at Hammonton at between 230 and 310 feet from the surface is the same as the great Atlantic City water horizon at from 780 to 860 feet is interesting and important. So, too, is the evidence from the Cape May well, that these same beds, which occur at Cape May at 900 feet, are not water-bearing at that point, although they furnish a good supply all along the coast between Harvey Cedars and Wildwood.

FLOODS.

Heavy freshets occurred on many rivers last spring, due to a warm rain on February 28th, following a prolonged cold spell, with considerable snow. On the lower Passaic, particularly, and on the Delaware they were so high and so much damage was done that widespread attention was directed to them. Mr. C. C. Vermeule, whose previous work on the Water Powers of the State had fitted him particularly to investigate the causes and conditions of these floods, was immediately authorized to study them. In the field work he was assisted by Mr. P. D. Staats and Mr. George E. Jenkins. The results of his investigations are given in detail in his report, Part I. of the accompanying papers, but attention is invited here to some of his conclusions.

On the Delaware river, at Easton, the flood was as high as any known at that point, but at Stockton, where there are well authenticated marks, it was four inches lower than the flood of 1841.

On the smaller streams of the State, including the head-waters of the Passaic and Raritan, the water was no higher than in the freshet of 1896 or in 1882, but the 1902 freshet was remarkable

in the much longer duration of high water. In consequence of this long-continued heavy run-off, the flat lands on the Passaic, above Little Falls, were covered to such an unusual extent that the freshet reached a dangerous height on the lower Passaic. Here it was higher than any freshet since 1810, although it did not exceed the flood of that date. Since the flood did not reach exceptional heights on the smaller streams, it is certain that the water was not precipitated into them at any unusual rate. This being the case, the extreme height on the lower Passaic cannot be ascribed in any degree to deforestation. Moreover, it is certain that there was as much, if not more, forest in 1810, when the present flood was equaled or exceeded, than at present.

Particular attention is invited to that portion of Mr. Vermeule's report respecting the height of the flood at Little Falls and Paterson, and his conclusions regarding the control exercised by the rock reef and Beattie's dam at Little Falls. These conclusions are of the utmost importance in view of the plans which were made by the Passaic Drainage Commission to lower the dam twenty inches in order to relieve the flat lands above Little Falls. A portion of this work has been accomplished, but its completion has been opposed on the ground that the danger from excessive freshets on the lower Passaic would thereby be greatly increased. This fear arises from an entire misapprehension either (*a*) of the nature of the work contemplated, or (*b*) of the factors controlling the flow of the river during extreme freshets.

Mr. Vermeule's observations show that the discharge of water during great floods, and, therefore, the height of the freshet below Little Falls, is determined solely by the constricted channel between Two Bridges and Beattie's dam, and not by the dam itself nor the reef of rock directly above it. The dam might be entirely removed without materially affecting the height of the water between Little Falls and Paterson during maximum freshets. The flood-marks of last spring's freshet between Little Falls and Two Bridges show conclusively that Beattie's dam exercised no control whatever over the maximum rate of discharge. This conclusion is in entire accord with evidence drawn from observations of the great flood of September, 1882, and of all later freshets. Therefore, the fear that lowering the dam as proposed would endanger Paterson and other points along the lower Passaic is entirely groundless.

Although the proposed improvements would not in any way in-

crease the height of freshets below the dam, nor prevent the meadows from being flooded in extreme high water, nevertheless, they would, if carried to completion, be of great benefit in carrying off the water from the meadows after the maximum stage had passed. Under present conditions the lowlands remain saturated and submerged two or three weeks, or even sometimes months, after the river has passed its flood stage. During this period—*i. e.,* when the stream is bank-full, and discharging about 3,000 to 6,000 cubic feet per second, or one-fifth of its maximum flood discharge—Beattie's dam is a controlling factor in the stream-flow. The proposed lowering of the dam twenty inches and the lowering of the reefs above the dam would at this time give very substantial relief to the wet lands above, and would in no way whatever affect detrimentally the lands below the dam. It is important that these points be emphasized, since so much misapprehension prevails.

Attention is also invited to that part of Mr. Vermeule's report in which he suggests the possibility of creating storage reservoirs along the upper Passaic, whereby the danger of disastrous floods on the lower Passaic may be averted, the value of the existing water powers at Little Falls, Paterson and Dundee enhanced, the summer flow of the river greatly increased and the pollution of the lower river by sewage diminished. The possibilities contained in this suggestion should be thoroughly canvassed in view of the urgent necessity of diminishing the contamination of the Passaic below Paterson.

Mr. Vermeule's full report is commended to the careful attention of all persons interested.

FORESTRY.

During the past year the following Forestry Bulletins have been published and widely distributed: No. I., Forest Reservations in the Pines Belt of Southern New Jersey, by John C. Smock. No. II., Does Forestry in New Jersey Pay? by F. R. Meier. No. III., Practical Aid to Landowners in Handling Forest Lands—A Plan of Co-operation by the Geological Survey. A few copies of each are still available for distribution.

In order that wider knowledge may prevail of the terms upon which the Geological Survey can assist landowners in forestry work, Bulletin III. is herewith reprinted.

PRACTICAL AID TO LANDOWNERS IN HANDLING FOREST LANDS.

A PLAN OF CO-OPERATION BY THE GEOLOGICAL SURVEY.

"Many persons realize that the common methods of treating forest land and harvesting the timber crop are wasteful in the long run, although they seem to yield the greatest immediate returns. A general lack of knowledge as to other methods, however, stands in the way of any widespread improvement. In many European countries forests are systematically treated, and made to yield a continuous income at the same time that the forest, as a whole, is preserved and propagated. For the past eight years forestry methods have been applied to a three-thousand-acre tract in Bergen county, and an annual return of five per cent. has been secured. During the eight years $25,000 worth of timber has been cut off, yet the forest is worth more now than when the experiment commenced, and, under the plan pursued, cutting can continue indefinitely, with equally good results.

In many cases trees may be planted with considerable profit. This is particularly true of the cottonwood, locust, black walnut, catalpa, tulip tree, smooth-bark pine, white pine, and, in some localities, the basket willow. A catalpa plantation, eleven years old, has been known to have a net value of $190 per acre, and a locust plantation, sixteen years old, of $148 per acre. In 1870 a grove of large, thrifty locust trees, thirty-six to thirty-eight years old, near Holmdel, yielded a gross return of $1,200 per acre for fence posts alone, and other instances are known where gross returns of $2,400 per acre have been realized. These results were obtained from the "waste land" on farms.

In order that similar work may be started in other parts of the State and that a better knowledge of forestry methods may prevail, the Geological Survey is prepared to co-operate with landowners to this end, so far as the funds at its disposal may permit.

Upon application from the landowner, the Survey will send a trained forester, who has had practical experience in the management of timber lands in the State, to examine the tract and to give practical advice for the improved treatment of the area in ques-

tion, either in respect to handling the present forest or in planting for the future.

Many persons think that only wealthy men can afford to place their land under forest management. This is a mistake. The object of forestry is to cut trees in such a manner that valuable successive crops can be raised in the shortest time, without injuring the producing power of the forest, *and at a profit.* The methods to be pursued vary under different conditions, but in all cases one aim is present—*to make the business pay, both now and in the future.* The farmer should be just as much concerned to make his woodlot pay the largest possible profit as he is to secure the largest returns from his orchard or his cornfield. But often this is not the case. The woodlot is left to take care of itself, whereas, in many cases, its value could be greatly increased, with but little additional labor or expense, if wise methods of cutting and planting were pursued.

In various parts of the State there are considerable areas of land which are valueless for agricultural purposes, but which may be of considerable value for forest purposes. These are often held in tracts of one thousand acres or over, but, under present conditions, they are often a source of expense, rather than profit, to their owners.

It is the desire of the Survey to render practical assistance to both classes of owners, and, therefore, requests for advice will be considered for tracts of any size, from five acres upwards. The applications will be considered in the order in which they are received, but precedence may be given to the lands most likely to furnish useful examples.

The conditions under which the Survey will undertake this work are stated in the following agreement:

TIMBERLAND AGREEMENT.

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The Geological Survey of New Jersey and John Doe, of ...., do mutually agree together as follows:

1. The Geological Survey, in pursuance of investigations in forestry, and in order to disseminate a knowledge of improved ways of handling forest lands, shall, after personal study, on the

ground, by its Forester, prepare a plan for harvesting the forest crop and reproducing the forest on the lands of the said John Doe, situated and described as follows: ....

....

....

2. The said plan shall be prepared for the purpose of increasing the present value and usefulness of the said land to its owner and to perpetuate and improve the forest upon it.

3. Upon the completion of the said plan and its acceptance by the said John Doe, the Geological Survey shall supervise the execution thereof, so far as it may deem necessary.

4. The cost of executing the provisions of this agreement shall be paid as follows: (*a*) The salaries of all employes of the Geological Survey engaged in fulfilling this agreement shall be paid by the Survey. (*b*) Actual and necessary expenses for traveling and subsistence of the employes of the Survey working under this agreement shall be paid by the said John Doe. Expenses under this paragraph are estimated for the preparation of this plan at .... dollars. (*c*) The Survey shall not participate, in any degree, in the receipts and expenses arising from said land, further than as specified in (*b*) above.

5. The Geological Survey shall have the right to publish and distribute, in its reports or otherwise, the said plan and its results, for the information of landowners and others whom it may concern.

6. This agreement may be dissolved by either party, upon ten (10) days' notice given to the other.

(Signed) ....
(Signed) ....

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The plan above mentioned, being now completed, is accepted, and will be carried out, under the conditions and during the validity of the above agreement.

(Signed) ....

....

Applicants for advice should specify the acreage and situation of their lands, the latter by county and township. Full details as to the character of the forest are especially desired, in order to avoid delay. Applications may be made at any time, and

the State Geologist will be glad to correspond with landowners regarding their properties. The Geological Survey, however, reserves the right to withdraw the offer herein made, without further notice, if the interests of the Survey demand it."

Numerous inquiries have been received in response to this circular and reports have been made to the following persons after an examination of their woodlands by Mr. F. R. Meier, who has acted as consulting Forester to the Survey:

Mr. Edward Colson, Daretown, Salem county; Mr. J. P. Whitney, Glassboro; Mr. Louis Du Bois, Holmdel, Monmouth county; Mr. Morris T. Sherrerd, Engineer and Superintendent of the Newark Water Department.

The largest tract examined was that of the Newark Water Department, surrounding the storage reservoirs in the Pequannock valley, in Passaic, Morris and Sussex counties. On this tract the foremost aim is, of course, the preservation of the water-supply from contamination and the securing of as equable a flow as possible. This is best accomplished by preserving the water-shed in forests, but its attainment is not inconsistent with a scientific and profitable cutting of the timber for revenue. Mr. Meier has examined the tract and outlined a plan of management by which the oldest, diseased and defective trees will be removed to make room for more vigorous growth. Selective cuttings will also be made of trees for the market, and the growth of seedlings will be encouraged. Owing to the great extent of this tract and its consequent importance as an object-lesson in scientific forest management, the Geological Survey has arranged to have Mr. Meier supervise the execution of the plan, in accordance with the terms of the above agreement.

A portion of the land of Mr. Colson was found to be admirably adapted to the cultivation of the basket willow; and accordingly a report regarding its culture was prepared by Mr. Meier. So much of this report as is of general interest is published in Part III. of the accompanying papers.

Forest Fires.—The loss to the State from forest fires has been frequently referred to by the State Geologist. In the Annual Report for 1895 a list of forty-nine fires in Atlantic, Ocean and Burlington counties alone is given, which burned over 60,000 acres and did damage estimated at several hundred thousand

dollars. In order to determine exactly the effect of repeated fires upon the forests of the State, accurate valuation surveys were made in 1897 by Mr. Gifford Pinchot, now chief Forester of the United States. These surveys included timber which had been protected from fire and that which had been repeatedly burned over. These showed that the yield of timber from the burned tracts was only one-third the volume of what it would be if protected from fire, and only one-sixth of what the land is capable of producing under careful management. Moreover, under present conditions, the wood is coarse, knotty and fit only for cordwood, whereas, protection from fire would insure dense stands of timber and tall, straight trees, free from knots.

In spite of the facts published in the Annual Reports for 1895, 1898, and 1899, showing the great loss to the State by these fires, which, in the majority of cases, could have been easily extinguished if promptly attacked by an organized force, each year has seen a continuation of the destruction. The past year has been no exception to this rule, although it was marked by heavy rains at intervals during the period when fires are most prevalent, and therefore the damage was not so great as in some years. Nevertheless, the recent investigations of Mr. Meier show that in 1902, from April to October, inclusive, there were sixty-five forest fires in the State, which burned over an area of 98,850 acres and did damage conservatively estimated by him, after actual observation upon the ground, at $168,323. Twenty-one of these were set by locomotives, twenty-two by farmers burning brush or clearing land, six by hunters, two were incendiary and the rest resulted from miscellaneous causes.

During the past year more fires were started by carelessness in burning brush, clearing land, &c., than by locomotives, although the difference in numbers is not great. But when the acreage burned over and the loss are compared we find a marked difference. The twenty-one fires started by locomotives burned 85,203 acres, causing damage to the amount of $110,602, whereas, the twenty-two fires caused by carelessly burning brush swept over 4,495 acres, with loss of $33,976. A single fire in Burlington and Ocean counties, started by a locomotive, swept over a tract twenty miles long and from one to eight miles wide and lasted ten days. The damage by this fire alone is conservatively estimated at $75,000. No effort was made to extinguish it and it was

finally put out by rain. The most destructive fire caused by burning brush was one near Bridgeton, where 800 acres of thirty-year old oak and pine of excellent quality were burned, causing a loss of $16,000. Leaving these two fires out of account as perhaps being unusual, we nevertheless find that the twenty other fires set by locomotives burned 10,203 acres, with loss of $35,602, as against the twenty-one other fires from burning brush, which burned only 3,695 acres, with loss of $17,976. It is evident, therefore, that the fires caused by railroads were last year by far the most destructive, although not the most numerous.

The reason for this is perhaps twofold. Fires started by burning brush or clearing land are frequently confined to more or less isolated tracts of timber and therefore cannot spread so widely. Moreover, it more often happens that some effort is made to extinguish these fires or at least to confine them within limits. In the case of the railroad fires, however, these more commonly start in the great unbroken stretches of pine, where houses are almost entirely wanting. Unless discovered promptly by the railroad section men, no efforts are ordinarily made to extinguish them. The smoke, indeed, is commonly seen from the nearest town, but it is no one's business to fight the fire and, therefore, no attention is paid to it unless it threatens the town. Nearly all the fires during the past year could have been extinguished with little loss, if attacked promptly by a well-organized force under competent direction.

Arranged by counties, the record stands as follows:

Atlantic	11	fires,	11,417	acres	burned,	damage,	$32,463 00
*Burlington	5	"	25,128	"	"	"	25,100 00
Cape May	13	"	1,950	"	"	"	4,705 00
Cumberland	7	"	3,225	"	"	"	28,018 00
Camden	1	"	400	"	"	"	6,000 00
Gloucester	5	"	830	"	"	"	4,220 00
Mercer	1	"	15	"	"	"	150 00
Monmouth	2	"	620	"	"	"	5,900 00
*Ocean	5	"	53,080	"	"	"	54,297 00
Passaic	2	"	1,125	"	"	"	4,500 00
Morris	1	"	350	"	"	"	700 00
Salem	4	"	480	"	"	"	2,480 00
Somerset	5	"	100	"	"	"	400 00
Sussex	4	"	130	"	"	"	390 00
							$168,323 00

* One fire is counted in both Burlington and Ocean counties.

The above estimates take into account only the damage to the timber itself, but do not include the less easily estimated damage done to the soil, which is impoverished by repeated burnings. The layer of vegetable mold which is always found on the floor of undisturbed forests and which is vitally necessary to the propagation and growth of the forest, is gradually destroyed by repeated burnings. It is recognized by all foresters that this layer of humus is an important factor in preventing evaporation from the soil, moderating extremes of temperature and preventing the shifting of the sand beneath by wind and rain. If this is destroyed the reproduction of the forest is practically impossible for many years. In some parts of the pines belt, this condition has already been reached, and in all regions subject to repeated fires it is rapidly approaching. The annual damage done by fires in destroying the humus is not easily expressed in dollars and cents, but it must not be overlooked.

Many persons are inclined to question the damage caused by these fires which annually sweep over portions of the State. The reason for this is that the freshly devastated lands are compared with the forests which are now in existence, and which, for the most part, have themselves been burned over repeatedly. This is wrong. Comparison should be made with the forests which grew originally or which might still be flourishing if the land had been protected. Small, scattered tracts of old timber have locally escaped fire and demonstrate by their size and value that the soil, where not sterilized by repeated burnings, is capable of producing a large tree growth. On the other hand, treeless, nearly barren areas, like the Plains in Burlington and Ocean counties, show the results of repeated fires, and indicate only too surely the condition to which a large portion of the pines belt will ultimately be reduced unless forest fires are prevented. As eminent an authority as Mr. Gifford Pinchot has declared that "the complete impoverishment of southern New Jersey is close at hand unless the fires can be stopped."

Methods of Prevention.—Under existing legislation, the duty of fighting forest fires has been left to the townships. They have had power to appoint fire marshals and make appropriations for this work, but no effective good has been accomplished. As shown by the number and extent of fires during the past season, the means at present employed are totally inadequate. Very few of the

townships make any effort to prevent or extinguish fires, leaving it to individual effort. Not a single township has availed itself of the provisions of the law* passed by the last Legislature, nor has any determined effort been made to enforce its regulations regarding the burning of brush, charcoal pits, &c., which caused over 30 per cent. of the fires last year. In the opinion of some, not five townships will accept the provisions of the act in the next ten years.

Individual effort is totally ineffective in the vast majority of cases, for a variety of reasons. The most serious objections to the present methods of fire-fighting are (*a*) lack of unity of effort and centralization of authority; (*b*) general apathy, except where the fire has attained great proportions and threatens some town or farm buildings; (*c*) lack of knowledge as to exact location of the fire in its incipient stages; (*d*) delay in attacking the fire; (*e*) frequent cessation of efforts before the fire is completely extinguished.

In the Annual Report of the State Geologist for 1898, after the whole subject had received careful investigation, a comprehensive plan was presented for a State Forest Service. It was there shown that successful organization against fires should attain (1) the rapid and accurate location of the fire; (2) the speedy arrival of the fighters at the scene of a fire, and (3) vigorous and intelligent action on the part of the fighters. Whether the proposed plan was the best that could be devised, or whether a simpler organization might not be equally effective, is a question which can only be determined after trial. It is beyond question, however, that no effective measures against forest fires can be expected within the next decade unless the State takes the matter in hand. The studies of this department indicate that a maximum annual expenditure of $10,000 by the State in establishing and maintaining a State Forest Service will largely prevent this annual devastation. Since the area to be protected is, roughly, 1,400,000 acres, the expenditure of about three-quarters of a cent per acre per annum cannot be regarded as excessive.

The organization should have an expert forester at its head, who should not only have charge of all efforts in fighting fires, as well as the enforcement of the forest laws, but should also give advice and instruction, free of charge, to residents of the State,

*An act concerning forest fires and the prevention thereof. Chapter 139, Laws of 1902.

upon all matters relating to the protection, care and management of woodlands, both by letter and by personal inspection of forest areas, and who, by all means in his power, should create an enlightened public sentiment on forestry matters.

There should also be numerous fire wardens, at points throughout the region subject to fires, who, in consideration of a small sum monthly, should bind themselves to fight fires whenever they occur within their territory. Provision should also be made for the temporary employment of large numbers of men to fight great fires, which cannot be extinguished except by a large force. It is not intended here to present the plan in all its details, but only to emphasize the conviction of the State Geologist and various members of the Survey staff, reached after careful study and consultation with many persons familiar with the conditons, that a State Service organized along these lines, with the right kind of officers, would not only be efficient in extinguishing fires before they had attained great headway, but that it would arouse public opinion to the usefulness of forests and the danger which threatens them. The safety of the forests in any region must ultimately rest upon an enlightened local sentiment, and without this, efforts to protect them cannot be entirely successful.

Since local measures are not effective; since the matter is beyond the power of townships to control; since the increasing devastation is a matter which concerns the State at large as well as the regions immediately affected, the State, out of its abundant resources, should promptly establish a forest-fire service. The question cannot be solved by postponing action, for postponement only aggravates existing conditions. Prompt and efficient action is demanded, and the demand should not go unheeded. Some such plan as that proposed above should be put in operation at once, in the district most exposed to fire. The State annually spends thousands of dollars to enforce the game laws and protect the game from extinction, although, at the same time, large amounts of game are annually killed by these fires. It surely should exercise its police powers to preserve its forests, which are of great value and importance, not only for the production of timber, &c., but for their indirect effects upon the soil, the water-supply and the climate.

CO-OPERATION OF THE UNITED STATES GEOLOGICAL SURVEY.

Under the agreement entered into in 1891 with the United States Geological Survey for co-operation in geological work, a portion of the Highlands was surveyed in four succeeding years, but work was suspended for a number of years. During the past season, however, at the urgent request of the State Geologist, it was resumed. The Franklin folio, showing the geology of a considerable region around Franklin Furnace, together with descriptive text, has been prepared by Dr. J. E. Wolff for publication by the United States Geological Survey, and is now in the hands of the engravers.

Under Dr. Wolff's direction, moreover, field work was continued in the Highlands, with a view of completing the area contained in the Passaic quadrangle of the United States Survey maps. Upon the completion of this work, data will be in hand for the publication of another folio, which will show the geology of another large area, in the northern part of the State. The expense of this work is borne by the national organization, thus permitting the funds of the State Survey to be used in other directions.

The Hydrographic branch of the United States Geological Survey, in response to requests from many leading citizens of the State, as well as from the State Geological Survey, late in the year, made arrangements for a series of stream measurements upon New Jersey rivers, for the purpose of determining the stream-flow during the various stages of high and low water. This work supplements and carries forward that already done by this department, the results of which were presented in Mr. C. C. Vermeule's Report upon the Water-Supply, Volume III. of the Final Report series.

MUSEUM.

Early in the year the cases and specimens which had been on exhibition at the Pan-American Exposition were returned from Buffalo and replaced in the Museum. Owing to lack of cases and shelves, much of the new material, secured for exhibition at Buffalo, cannot be displayed to advantage. The same is also true of the new material which is constantly coming into possession of

the Survey. Under present conditions, there is nothing to be done but to store this material in boxes in the basement of the State House.

LIBRARY.

The Survey receives, as exchanges, reports and maps from other Surveys, both in this country and abroad, as well as numerous trade journals and pamphlets from individuals. In addition to these, several important geological and mining periodicals are received by subscription, and some important books needed for reference are purchased.

In these ways the Library received during the year 27 bound volumes, over 200 unbound volumes of periodicals and reports, 326 pamphlets and nearly 200 engraved maps. The proper care of these, even with the minimum amount of attention and simplest method, demands considerable time.

PUBLICATIONS.

During the year, the Annual Report for 1900, an 8vo, containing xxviii. plus 178 pages, and illustrated with six inset plates, two figures in the text and two maps, has been published and was distributed in July. The exchange list of the Survey contains the names of 285 libraries and other surveys, 332 newspapers and periodicals and 2,945 individuals. All requests for reports are filled so far as the supply on hand permits, the only expense to the recipient being the cost of transportation. The demand for the reports from parties without the State, wishing information as to its resources, is large and encouraging.

Three forestry bulletins have been published and distributed—Bulletin I., Forest Reservations in the Pines Belt of Southern New Jersey, by J. C. Smock, 12 pages, 1 map; Bulletin II., Does Forestry in New Jersey Pay? by F. R. Meier, 9 pages; Bulletin III., Practical Aid to Landowners in Handling Forest Lands—A Plan of Co-operation by the Geological Survey, 6 pages.

The Report on Glacial Geology, Volume V. of the Final Report series, is in press at this writing, and will be ready for distribution soon.

The following sheets of the large scale maps were published during the year: Morristown, in December, Atlantic City, in October, and Trenton sheet just after the year closed. Copies of these sheets have been sent to a few libraries in the State, to other Geological Surveys, to the Managers of the Survey, and to the various State departments. Further distribution is by sale at the regular charge of 25 cents per sheet—a charge which barely covers the cost of printing and mailing.

A new edition of sheet No. 9 of the old Topographical Atlas was also issued and placed on sale.

PART I.

Report on the Floods of February 28th to March 5th, 1902.—Effect of Proposed Drainage Works on Passaic Floods.

By C. C. VERMEULE.

Notes of the Floods of February 28th to March 5th, 1902.—Effect of Proposed Drainage Works on Passaic Floods.

BY C. C. VERMEULE.

On the opening days of March last there were freshets on all of the streams of the northern part of the State which were high enough to be worthy of study and comparison with previous high floods. They did not, as a rule, exceed in height previous floods of record. On the lower Passaic, however, the flood was the highest since 1810, and considerable damage was done at Paterson.

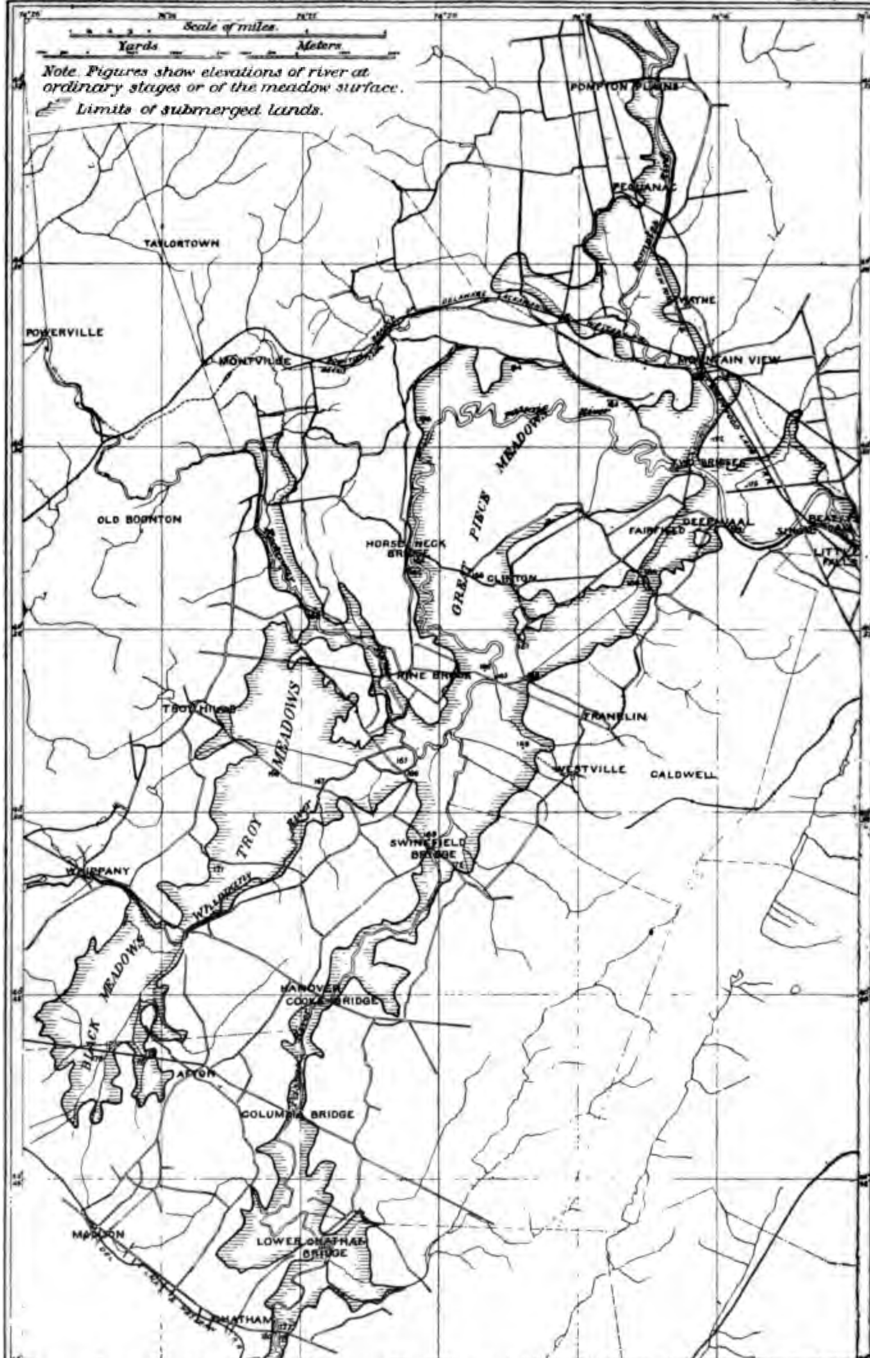
When the Report on Water-Supply, of 1894, was written, the flood of September, 1882, on the Passaic, was taken as a maximum, and there appeared to be no evidence that any higher water had occurred on that stream or on the Raritan, and possibly none so high, except in 1810. On February 6th, 1896, however, freshets occurred which were discussed in the annual report for that year. These were higher on the Raritan and the several Highlands branches of the Passaic than any previous freshets for which we have reliable data; but on the Passaic, below Two Bridges, the water was not so high in 1896 as it was in 1882. We are again called on six years later to record another notably high freshet, and it becomes interesting to investigate its cause, and endeavor to ascertain whether there is any reason to infer that similar high freshets are occurring more frequently than during the early part of the nineteenth century.

It is well to direct our attention first to the meteorological conditions which produced the freshets of last March. The precipitation through the winter had been fully up to the normal;

and, as is usual in the month of February, the ground was well filled with water. The entire month of February was cold, averaging 4 degrees below the normal temperature, and there had been, from the 21st to the 26th, precipitation amounting to 2.65 inches in all. The weather, up to the 26th, had been so cold that practically all of this water must have remained on the ground in the form of snow or ice. The snow, which was compact, ranged from 8 inches to 1 foot in depth on the 28th. On the 25th the mean daily temperature of the Highlands was 26.5 degrees; on the 27th it had risen to 43 degrees. The streams began to rise early on the 26th and were already out of their banks on the morning of the 28th, on which day the average rainfall in the northern part of the State amounted to 1.61 inches, and the rivers rose rapidly. This was followed by 0.91 inches additional on the 1st and 2d, and 1.05 inches on the 5th of March, making the total precipitation 6.22 inches.

As a result of these conditions, during the eight days from February 28th to March 7th, inclusive, the Passaic discharged over Dundee dam 86 per cent. of this precipitation, or a quantity of water equal to 5.35 inches of rainfall on its catchment. This flood, therefore, exceeds in volume the greatest previous one for which we have a volumetric record, viz.: September, 1882, by over 44 per cent. Fortunately, the rainfall and the thaw were distributed over eight days, and precipitation was not so concentrated as in February, 1896; consequently the maximum rate of discharge and the height of this flood were not commensurate with its great volume, and exceeded that of 1882 on the Lower Passaic by only 24 per cent.

On the Delaware the flood of last March was 9 inches lower at Lambertville, and 4 inches lower at Stockton, than the flood of 1841. On the Raritan and most of the other streams of Northern New Jersey it was also lower than in 1896. Only the Lower Passaic, Delaware and Pequest exceeded the records of 1896 and 1882. On these, owing to topographic peculiarities, the maximum rate of discharge is more nearly commensurate with the volume of run-off than is the case with more torrential streams.



MAP OF LANDS SUBMERGED BY THE FLOODS OF MARCH, 1902 ON THE PASSAIC.

PASSAIC CATCHMENT.

The topography of the Central Passaic Valley and the relative position of the several branches of the Passaic are shown by Plate I. Between Two Bridges and tidewater, at the city of Passaic, the stream receives no important affluent. This portion of the stream we have designated the Lower Passaic. We have records of its discharge at Little Falls and Dundee, and of its height at Paterson, all of which are in close agreement.

Two Bridges is at the confluence of two branches having nearly equal catchments, viz.: the Pompton and the Upper Passaic.

The northerly affluent, the Pompton, is formed by the confluence of the Ramapo, Wanaque and Pequannock, all of which meet about six miles north of Two Bridges, at the village of Pompton. The catchment of the Pompton, which lies mostly upon the Northern Highlands, is mountainous and forested. There is very limited opportunity for the flood-waters to spread and accumulate, as the valleys above Pompton are narrow and confined, consequently the floods are discharged promptly and the maximum rate of discharge is high. The southerly affluent, the Upper Passaic, has large areas of flat land over which the flood-waters spread as indicated by the shading in Plate I. These flats extend to include Great Swamp, not shown on Plate I., which is almost at the head-waters of the stream, but two important branches, the Rockaway and Whippany, have their catchments upon the Southern Highlands, so that about one-half of the catchment of the Upper Passaic is hilly or rolling, with considerable forest area.

The Passaic below Two Bridges reached the bank full stage of 4,000 cubic feet per second at midnight on the 26th of last February, and by noon on the 28th had risen to over 12,000 cubic feet per second. It then began to rise more rapidly, reaching a maximum of 22,677 cubic feet per second on March 2d, at 6:30 P. M. It continued at a very high stage, exceeding 21,000 cubic feet per second, for 24 hours, or until 6:30 P. M. on March 3d, after which it subsided in its customary, regular, but tardy manner. Owing to later rains the river did not get within its banks for about two weeks, but the flood which we are considering was

practically over by 6:30 P. M. of March 7th. During the eight days from February 28th to March 7th, inclusive, the total quantity of water flowing over Dundee dam amounted to 10,-219,443,630 cubic feet. This quantity can be better understood if we consider that it would fill a square reservoir measuring one mile on each side and 366 feet deep. It would be sufficient, if stored and saved, to supply all the water used by Newark and Jersey City together for a period of over three years; but, for reasons which we have pointed out in the Report on Water-Supply, it is impracticable to conserve such flood-waters.

This year's flood on the Lower Passaic exceeded all others which we have heretofore recorded in any of these reports. During our studies of this flood, however, we have been able to verify marks of the flood of 1810 which have been pointed out from time to time, and have obtained other marks. From these we find that flood to have been six-tenths of a foot higher between Little Falls and Two Bridges than the recent freshet. An accurate survey of the channel of this part of the river, and well-ascertained slopes of these floods, enable us to compute that the maximum discharge in 1810 must have been 25,500 cubic feet per second, or 10 per cent. in excess of the flood of 1902.

It also appears that about forty years ago there was another freshet nearly as high as that of 1902. (There was such a flood on the Raritan in 1865. See Report on Water-Supply, page 214.)

The following tables exhibit in condensed form the leading data for the high freshets of which we have measurements:

TABLE A.

MAXIMUM RATES OF DISCHARGE ON THE PASSAIC AND ITS BRANCHES.

	Catchment, square miles.	September 22, 1882. Hours beginning to maximum.	September 22, 1882. Greatest discharge, cubic feet, per second.	February 6, 1896. Hours beginning to maximum.	February 6, 1896. Greatest discharge, cubic feet, per second.	March 2, 1902. Hours beginning to maximum.	March 2, 1902. Greatest discharge, cubic feet, per second.
Passaic, Dundee	822	66	18,265	44	17,217	91	22,677
" Little Falls..............	773	66	19,000	44	16,745	81	21,207
Ramapo at Pompton	160	24	10,540	24	8,731	54	7,049
Wanaque, at Pompton...............	101	24	6,666	11	7,203	54	6,187
Pequannock at Pompton..........	85	20	4,460	7	5,500	50	4,600
Rockaway at Boonton	118	36	4,800	16	5,445	51	4,540
Whippany at Whippany..........	38	...	....	10	3,200	47	2,600

TABLE B.

GREAT FLOODS ON THE PASSAIC AT DUNDEE SINCE 1876.

AREA OF WATERSHED 822.7 SQUARE MILES.

Date of Maximum Discharge.	Greatest discharge, cubic feet, per second.	Time from beginning of rise to— Maximum, hours.	Time from beginning of rise to— End, days.	Total discharge. In million cubic feet.	Total discharge. Inches on watershed
March 2d, 1902....................	22,677	91	8	10,219	5.35
September 25th, 1882.............	18,265	66	8	7,101	3.71
February 8th, 1896...........	17,217	44	8	6,083	3.18
December 12th, 1878...............	16,592	60	8	6,878	3.47
February 14th, 1886...............	12,452	60	8	5,729	3.00

Table A shows, in the columns headed "hours from the beginning to the maximum," the relative suddenness of the rise of the three great floods on any given stream. Thus, the very sudden, sharp rise of 1896 brought the main stream to a maximum at Dundee in 44 hours, whereas in 1902 it required 91 hours. On the branches the variation was still greater. In both cases the ground was frozen, but thawing, yet the contrast between the two is much sharper than between either and the September freshet of 1882. This makes clear the fact that the deficient

percolation due to frozen earth, to which too much importance is often attached, is less of a factor than the degree of concentration of rainfall. In considering the rate of precipitation we must, of course, treat all snow and ice accumulations as rainfall at the time when they were set free by melting. Another very important factor is the condition of the ground-water. A concentrated rainfall coming upon saturated soil will produce heavy floods at any season of the year.

As will be seen by reference to Table A, all of the branches reached a higher maximum in 1896 than they did in 1902; but, on the other hand, the main stream at Dundee and Little Falls was lower. A reference to Table B will show, on the other hand, that the total run-off of the stream during eight days was very much greater in 1902 than in 1896. This seeming paradox is fully explained by the fact that the maximum height on the branches is determined by the greater or less concentration of the precipitation, whereas on the lower stream the height of the maximum is determined by the extent to which the Great Piece meadow above Two Bridges is filled up, owing to the excess of inflow over the capacity of the channel below Two Bridges.

Taking the column of hours for a given flood, we have an exhibit of the chronological order or sequence of the maxima on the several branches and on the main stream. In order better to understand the movement of the flood-waters into and out of the large swamps on the river above Two Bridges, it is necessary to present more fully the sequence of the flood stages on the several branches, and this is done for the two floods of 1902 and 1896 in the two following tables:

TABLE C.

CHRONOLOGY OF THE FLOOD OF 1902 ON THE PASSAIC.

Point of Observation.	Hours from February 26th, 1902, midnight, when the Passaic reached bank-full stage to—			
	Beginning of rapid rise.	Maximum height.	Beginning of marked subsidence.	End of flood.
Passaic, at Little Falls	Uniform.	81	96	9 days.
Pompton, at Pompton Plains	"	54	72	7 "
Ramapo, at Pompton	38	48	57	....
Wanaque, at Pompton	42	92	95	....
Pequannock, at Pompton	36	48	120	....
Rockaway, at Boonton	43	51	101	....
Rockaway, at Pine Brook	Uniform	78	78	....
Whippany, at Whippany	42	47	47	7 days.
Passaic, at Hanover	Uniform.	96	104	9 "
Passaic, at Chatham	"	36	66	9 "

TABLE D.

CHRONOLOGY OF THE FLOOD OF 1896 ON THE PASSAIC.

Point of Observation.	Hours from beginning of rise on the Passaic, February 6th, 1896, at 10 A. M. to—			
	Beginning of rapid rise.	Maximum height.	Beginning of marked subsidence.	End of flood.
Passaic, at Little Falls	3	44	44	6 days.
Pompton, at Pompton Plains	Uniform.	13	Uniform.	66 hours.
Ramapo, at Pompton	"	23	"	3 days.
Wanaque, at Pompton	"	23	"	36 hours.
Pequannock, at Pompton	"	6½	"	24 "
Rockaway, at Boonton	"	16	17	48 "
Whippany, at Whippany	"	10	Uniform.	21 "
Passaic, at Pine Brook	7	17	41	6 days.
Passaic, at Hanover	Uniform.	24	36	6 "
Passaic, at Chatham	"	5½	53	....

For the flood of 1902 we have reckoned time from midnight terminating the 26th of February, when the Passaic reached 4,000 cubic feet per second, which is the bank-full stage at Two Bridges. For the 1896 flood we have taken the beginning of the rise, which was sudden and distinctly marked, as at that time the river was considerably below the bank-full stage.

The time of maximum height at the upper end of the flat lands is indicated by the record at Pompton Plains, Boonton, Whippany and Chatham. We have found that, in 1902, the maximum height was reached at these points in from 36 to 54 hours, the average being 47 hours, whereas the maximum height at Little Falls and Two Bridges, on the Lower Passaic, did not occur until the expiration of 81 hours, or 34 hours later than at the head of the flats. In 1896, the maximum at the head of the flats occurred at an average of only 11 hours from the beginning, whereas the maximum on the Lower Passaic was not reached until 44 hours had expired, a difference of 33 hours. The *agreement in time lapsed* between high water at the head of the flats and high water at the outlet at Two Bridges is marked in spite of the very great difference in the other characteristics of these two floods. As the difference of time was the same during the flood of September, 1882, it would appear that the time required for the flood to come down across the flats to Two Bridges is constant and independent of the height of the flood.

The swamp lands above Two Bridges and below Chatham, which are shown as submerged on Plate I., aggregate about 20,000 acres. The area of land covered with water during the flood of 1882 was determined by survey, and amounted to 20,012 acres. Our computations of the flood of 1882 indicated that at the end of 72 hours, or 3 days after the beginning of the rise, by which time the several branches had subsided within their banks, the accumulation of water on the flats amounted to 3,-480,000,000 cubic feet. A similar computation for the flood of 1896 shows that the greatest accumulation was at the end of 24 hours, and amounted to only 1,880,000,000 cubic feet, which accumulation was not materially diminished until after the expiration of 48 hours. (See annual Report for 1896, page 267.) Our studies of the flood of 1902 indicate that the accumulation on the flats at the expiration of 60 hours amounted to 1,734,-

000,000 cubic feet. At the end of 90 hours the accumulation was 1,272,000,000 cubic feet. From these figures it appears that the unusual height of the flood below Two Bridges was due, not to an unusual accumulation of water on the flats as a whole, but to the fact that after this water had begun to move down into Great Piece meadow, above Two Bridges, it was augmented unusually by the continued high rate of discharge of the branches, due to the successive storms, so that Great Piece meadow, immediately above Two Bridges, was filled up to an unusual degree, causing a high rate of discharge through the restricted channel from Two Bridges to Little Falls.

It must not be inferred that the submerged area shown on Plate I. was at any time level, like a lake, over the entire expanse. The slope of the flat lands is indicated by the elevations shown by the figures, which in some cases indicate the ordinary water level of the stream and in other cases the average level of the meadow surface. As shown by our chronology of the flood, in Tables C and D, high water occurred earliest at the points where the several branches come into the flats; and at this time, which was about midnight of the 28th, it was still 4.5 feet below its maximum height at Two Bridges, consequently there was a marked slope of its surface down through the flats, considerably greater than the slope of the valley. For 34 hours later, until the maximum discharge was reached at Little Falls, the water was subsiding at the upper end of the great pool, but rising at Two Bridges. During the next 15 hours it was discharged at Two Bridges as fast as it came in from above, and the out-flow was nearly constant. After this the discharge could be no longer maintained and the stream declined as it gradually emptied the flats of the accumulated flood-waters.

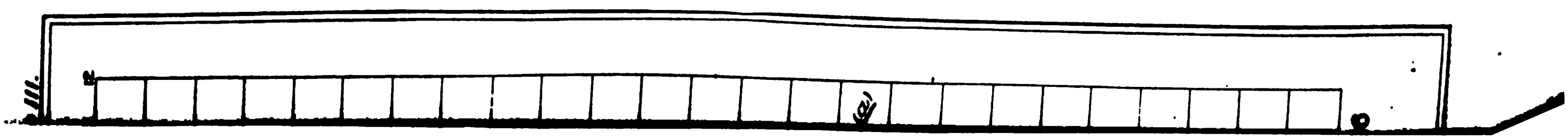
In the Annual Report for 1896 we traced the history of the flood of February 6th, 1896, and that of the flood of September, 1882, was traversed in the Report on Water-Supply of 1894 (page 155). The freshet of March, 1902, is less readily analyzed because of complications arising from the repeated heavy rains, but sufficient data have been collected to enable us to show graphically in Plate II. something of the history of the flood. On this plate the vertical lines and figures at the top indicate the date and hour, the lines being drawn at midnight, 6 A. M.,

noon and 6 P. M., for each day. The horizontal lines and figures at the left indicate the discharge in cubic feet per second on the several streams, so that such discharge can be found for any given hour during the flood.

Line "a" shows the curve of measured flow of the Passaic at Dundee dam, where the measurements are more satisfactory than at Little Falls, during the entire period of the flood. We have sufficient data at Little Falls to show that the curve of discharge there is closely parallel to the curve at Dundee. The discharge at Little Falls dam appears to have been remarkably steady from 9 A. M. to 12 P. M. of March 2d, varying but slightly from the maximum. Line "b" shows the curve of discharge of Pompton river at Two Bridges. This curve is a composite, made up of data obtained on the Ramapo at Pompton Steel Works, on the Wanaque at Pompton Lakes, and on the Pequannock above Pompton, together with a record kept at the head of Pompton feeder. We have been able to approximate closely the discharge of the Pompton from these data. Line "c" shows the rate at which the water came in from the Upper Passaic at Two Bridges.

The flood-waters of the Pompton reach Two Bridges much quicker than those from the other branches of the Passaic, as the latter have to work their way across a large area of flat land which must first be filled up to a sufficient height. As we have previously pointed out, (see Report on Water-Supply, page 155; also Annual Report for 1896, page 268) the result of this is that the flood-waters from the Pompton frequently flow up the southerly branch of the Passaic into the Great Piece meadow, this retrograde flow continuing until equilibrium has been established by filling up of the Great Piece meadow.

In Plate II., after having established the curve represented by the flow of the Pompton, shown by the line marked "b," we have taken the difference between the flow shown by this curve and the measured flow of the Lower Passaic, to represent the discharge of the Passaic past Two Bridges, and in this way have obtained the data to plot line "c." It will be noted that from about 10 P. M. on the 28th until 2 P. M. on March 1st, this curve goes below the horizontal line marked "0 cubic feet per second," or the line of no discharge. The reason for this is that during that time the flow of the Pompton past Two Bridges exceeded the


III.
(a)

amount of water flowing down the main Passaic from Two Bridges, and during that time, consequently, the water was flowing up stream at Two Bridges, into the Great Piece meadow. This curve "c," therefore, indicates graphically the occurrence of this peculiar phenomenon during the flood of 1902.

The remaining lines, marked "d" and "e," on Plate II., indicate the estimated discharge of the river after the completion of certain drainage improvements, to which we will refer later.

Plate III. shows similar data for the flood of February 6th, 1896, the several lines being lettered the same as corresponding lines in Plate II. As this flood presents a marked contrast to that of the present year, it is interesting to compare the two diagrams. The flood of 1896 was the result of a single sudden storm and thaw, which caused sharp rises on all of the branches of the Passaic.

Tracing the flood of 1896 on the diagram, Plate III., it will be noted that after 6 P. M. of the 6th inst. the quantity of water flowing down from the Pompton, at Two Bridges, shown by line "b," exceeded the discharge of the Passaic below Two Bridges, indicated by line "a," and it will be noted that line "a," showing the measured discharge of the Passaic, indicates that at 12, midnight, a maximum was reached, after which the stream fell off for seven hours. This first maximum, which nearly always occurs during great floods on the Lower Passaic, corresponds in time with the height of the flood on the Pompton, and the falling off is due to the fact that immediately after the Pompton begins to subside, the water from the southerly branches does not come down over the flats to Two Bridges rapidly enough to maintain the high rate of flow of the lower river, which has been established by the Pompton. At 7 A. M. of the 7th, equilibrium had been established at Two Bridges, and the waters coming down over the flats, from the southerly branch, again caused the main stream to rise, until it reached its maximum at 7 A. M. of the 8th inst., after which the main stream steadily declined for five days while it was drawing off the accumulated water on the flats above Two Bridges.

The discharge of the Pompton during this flood was quite accurately ascertained. Taking the difference between the discharge of the Pompton and that of the main Passaic, we are

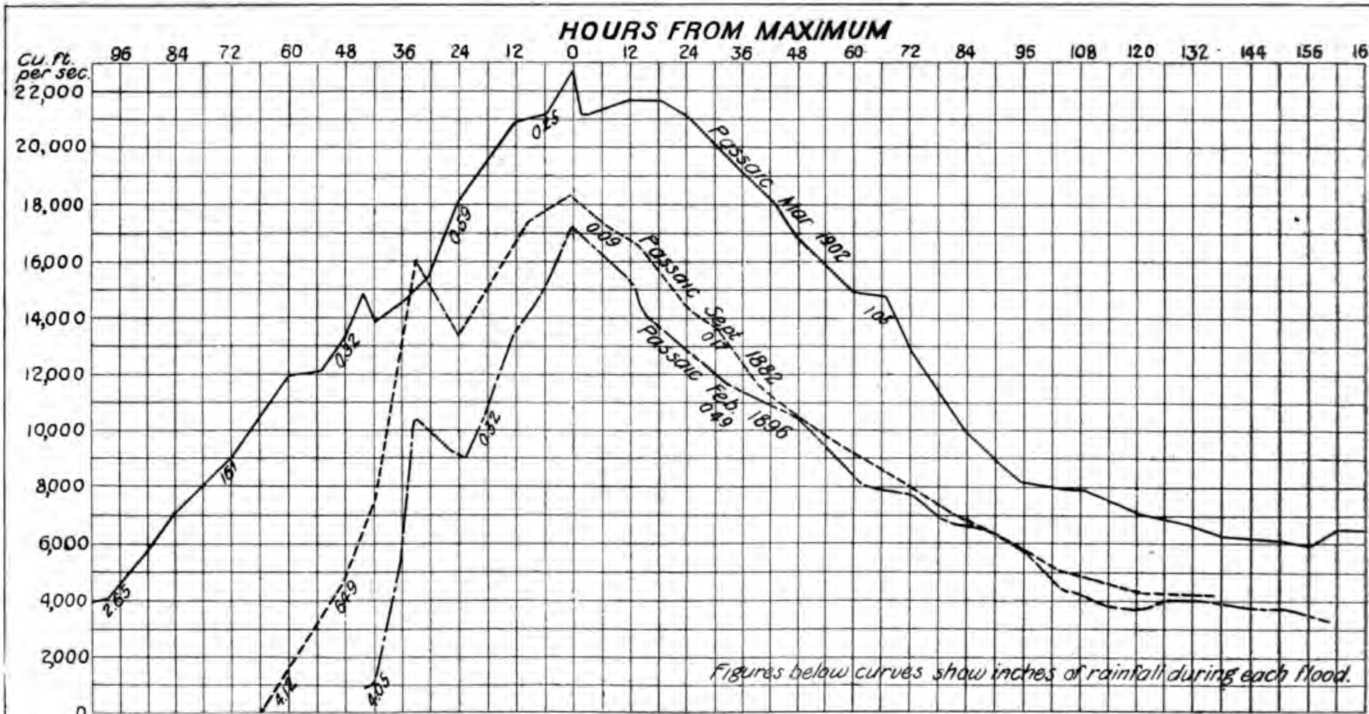
enabled to plot the curve of discharge of the waters of the Upper Passaic, past Two Bridges, as shown by the line "c." It will be noted that after 6 P. M. of the 6th inst. this discharge was a negative quantity until 3:30 P. M. of the 7th inst., during which time the waters of the Pompton were flowing up stream into the Great Piece meadow above Two Bridges, in the same way which was noted in Plate II. for the flood of 1902. This upward flow amounted to nearly 8,000 cubic feet per second at a maximum. As the Pompton declined at 3:30 P. M. of the 7th, a point was reached where the waters again commenced to flow downward from Great Piece meadow, and line "c" shows how these waters came in steadily at an increasing rate until 7 A. M. of the 8th inst., when the downward flow from Great Piece meadow amounted to 11,300 cubic feet per second. For the succeeding 12 hours the inflow and outflow from Great Piece meadow were about equal, after which the river steadily declined.

Lines "d" and "e" of the diagram refer to conditions after the completion of the proposed drainage works, and it is because these two floods are especially instructive as to the effect of these drainage works that we have presented them with such detail.

Plate IV. shows plotted curves indicating the discharge of the Passaic at Dundee during the three floods of 1882, 1896 and 1902. Time is indicated by the vertical lines drawn 6 hours apart, and is reckoned each way from the occurrence of the maximum for each flood, all being plotted with the maxima on the same vertical line.

The horizontal lines show the rate of discharge at any given time, in cubic feet per second.

The relative volume of the several floods is here shown graphically, being indicated by the relative height of the curves, and the figures just below the flood curve indicate the precipitation to which each flood was due. It will be seen that the period from the beginning to the maximum varies from 44 hours, in 1896, to 91 hours, in 1902. The first maximum, due to the inrush of the waters of the Pompton, coincides closely in time reckoned back from the principal maximum in the floods of 1896 and 1882, the interval being about 33 hours, but for the flood of 1902, it is about 45 hours. The parallelism of the curves representing the subsiding floods is quite remarkable, and indi-



COMPARATIVE DIAGRAM FOR PASSAIC FLOODS OF 1902, 1896 AND 1882.

cates that this curve is determined by the emptying of the stored water from the flats in each case.

It is interesting to compare the rainfall and run-off for these three floods, as I have done in the following table:

	Rainfall, inches.	Run-off, inches.	Computed evaporation, inches.	Percolation or loss, inches.
September, 1882	10.87	3.71	2.63	4.53
February, 1896	4.86	3.18	0.58	1.10
March, 1902	6.47	5.35	0.77	0.35

The column headed "Computed Evaporation" represents the evaporation for eight days, during each flood, as determined from the formulæ given in the Report on Water-Supply. Adding together the run-off and the computed evaporation, and deducting their sum from the rainfall, we have for each flood the quantities in the last column, representing the inches of rainfall percolating into the ground, or otherwise unaccounted for. These figures show that the rainfall causing the flood of 1902 is all accounted for excepting about 5 per cent., which is within the limits of error of the measurements, showing that there was practically no percolation, as is to be expected from the fact that this flood followed a rather wet period, and the ground was fully saturated at the beginning. In 1896, the flood followed a dry January, so that there was considerably more percolation. In September, 1882, the flood followed a very dry summer, so that a large percentage of the rain disappeared into the ground.

We may summarize our conclusions as to the Passaic flood of 1902 as follows:

1. Its cause was a heavy, warm rainfall upon accumulated snow and ice, setting suddenly free a large quantity of water. This water was precipitated less suddenly and in a less concentrated manner than in 1896, consequently *none of the branches of the Passaic* reached so high a stage as in 1896, although they remained high longer and discharged a larger total run-off in 1902.

2. *The main stream* reached a maximum of 22,677 cubic feet per second at Dundee, exceeding the flood of 1896 by 30 per cent., and that of 1882 by 24 per cent., and was higher than any other freshet since 1810.

3. The run-off discharged over Dundee dam during eight days amounted to 5.35 inches of rainfall upon the catchment, exceeding by 44 per cent. the volume discharged in 1882, and by 70 per cent. that of 1896.

4. The seeming paradox of a much higher maximum on the main stream than in 1896, while the branches were lower, is due to the modifying action of the flood storage on the flats above Two Bridges, which was sufficient to absorb and equalize a sudden, violent flood of moderate volume like that of 1896, but which was insufficient to similarly modify a flood so long continued, and of such unusual volume, as that of 1902.

5. The run-off was 86 per cent. of the total amount of rain and melted snow which caused the flood, and ordinary evaporation is sufficient to account for the balance, from which we conclude that percolation was very slight, not because the ground was frozen, for it had thawed out during this period, but because it was already saturated with water at the beginning of the storm.

EFFECT OF THE PROPOSED DRAINAGE WORKS ABOVE LITTLE FALLS ON THE HEIGHT OF PASSAIC FLOODS.

Considerable apprehension has been publicly expressed that in case the plans of the Passaic Drainage Commission are carried out at and above Little Falls, the height of such great floods as that of 1902 will be increased to a dangerous extent. This work was begun more than ten years ago, and was suspended for lack of funds in 1893. A number of persons invested in the bonds of the Drainage Commission appointed to carry out this work under the laws of the State, and the work was begun with due notice to all interests. The faith of the State may possibly be in some measure pledged to a reasonable prosecution of this drainage work, which has been beset with difficulties. As a sanitary and economic measure it is important to the future of the central valley, and no obstacle should be placed in its path unless there is a real, substantial foundation for the alarm expressed. This whole question of effect on floods had been carefully considered by several engineers of high standing, before the work was undertaken. In 1893 and 1894, however, the Committee

on Drainage of the Board of Managers of the Geological Survey, of which the late Lebbeus B. Ward, C.E., was Chairman, undertook a thorough investigation of all the plans of the Drainage Commission with a view to determining their sufficiency to accomplish the drainage of the flat lands, their effect on the floods of the lower river, their cost, &c. The writer served as consulting engineer to this Committee, and, after making surveys and an examination, reported very fully on these questions to the Committee. The reports were not published, but on the data then obtained the conclusion was reached that the improvements proposed by the Commissioners of Passaic Drainage would not increase, but, on the contrary, would tend to diminish the height of floods. This conclusion has since been fully supported by the additional data obtained during our investigations of the flood of 1896 and 1902, and it seems proper at this time to illustrate from these floods the reasoning on which it is based.

In the agreement made by the Commissioners with the Beattie Manufacturing Co., the following points are fixed as to the extent of the proposed improvements at Beattie's dam and in the channel up to Two Bridges. The dam is to be lowered twenty inches, the channel of the river above the dam to be excavated to a depth of not less than five feet below the lowered dam, and to a width of not less than 200 feet. The bar at Two Bridges is to be excavated to a depth of not less than four feet below the crest of the lowered dam, and to a width of not less than 200 feet below and 100 feet above the mouth of the Pequannock or Pompton river. It is also agreed to remove such obstructions in the Passaic, between said dam and the reef at Two Bridges, as shall insure a clear waterway of a width of not less than 200 feet, and a depth conformable to a grade line which at said dam shall not be less than 5 feet, and at Two Bridges not less than 4 feet below the level of the crest of the lowered dam. Flood gates are also to be inserted at the dam.

It will be noted that this agreement merely fixes a minimum improvement. The extent of the improvement, however, cannot very much exceed this, owing to the cost. The report of 1894, to the Committee on Drainage, pointed out that the most that could be done, keeping within the limits of a practicable cost, would be to increase the channel width to 250 feet and make its

depth 4 feet below the crest of the dam at Two Bridges, and 6 feet below the crest just above the dam, thereby giving a grade or slope to the channel of .12 in 1,000, which we found to be desirable. The side slopes of this rectified channel we made one perpendicular to one and one-half base. There is little doubt that even this scale of improvement very materially exceeds in cost the funds which will ever be available for the work, but for the purpose of this discussion we assume that the work may be completed to this extent in order to show the maximum possible effect on the height of floods. The proposed improvements of the channel are shown in profile on Plate V., and by cross-sections on Plate VI.

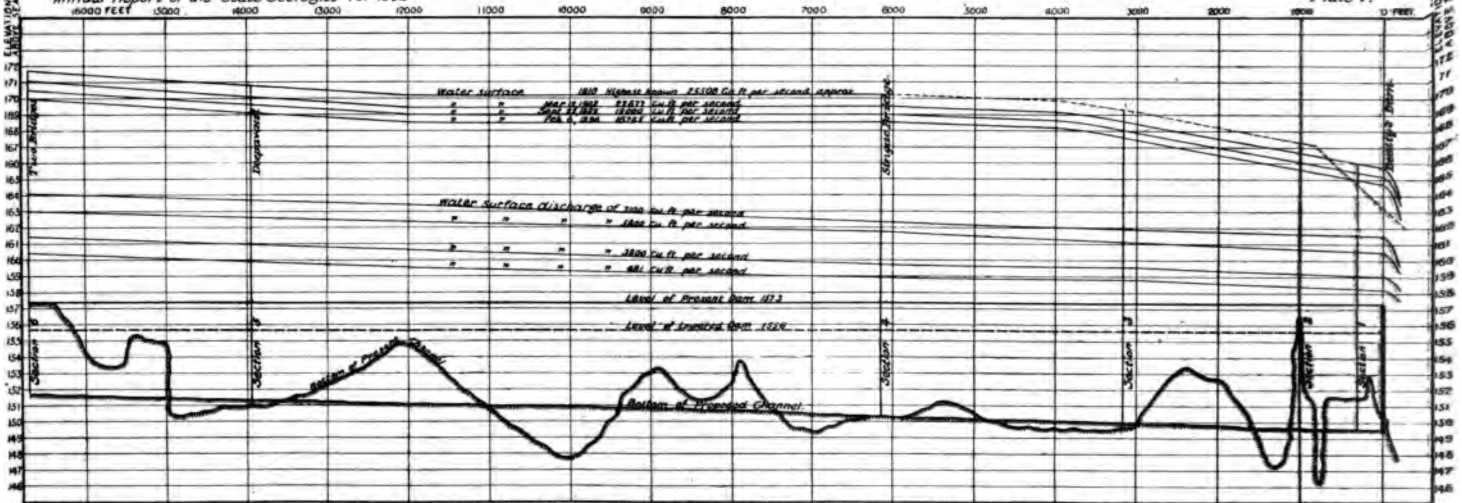
The result of such improvements would be a slightly increased cross-section of the river, and what is more important, a lower value of the coefficient of roughness, giving a higher velocity for a given slope. Our surveys and investigations show that the present obstructed channel has a coefficient of roughness, "n" in the Kutter formula, of .032, and it may be safely assumed that the improved channel would reduce this to .025. A lower value than this could not reasonably be expected during flood discharge, owing to the crooked course of the river. A computation based on the data furnished by our surveys shows that the effect of the improvements above indicated would be to reduce the height of the water at Two Bridges, for given stages of the river, to the extent shown in the following table:

TABLE E.

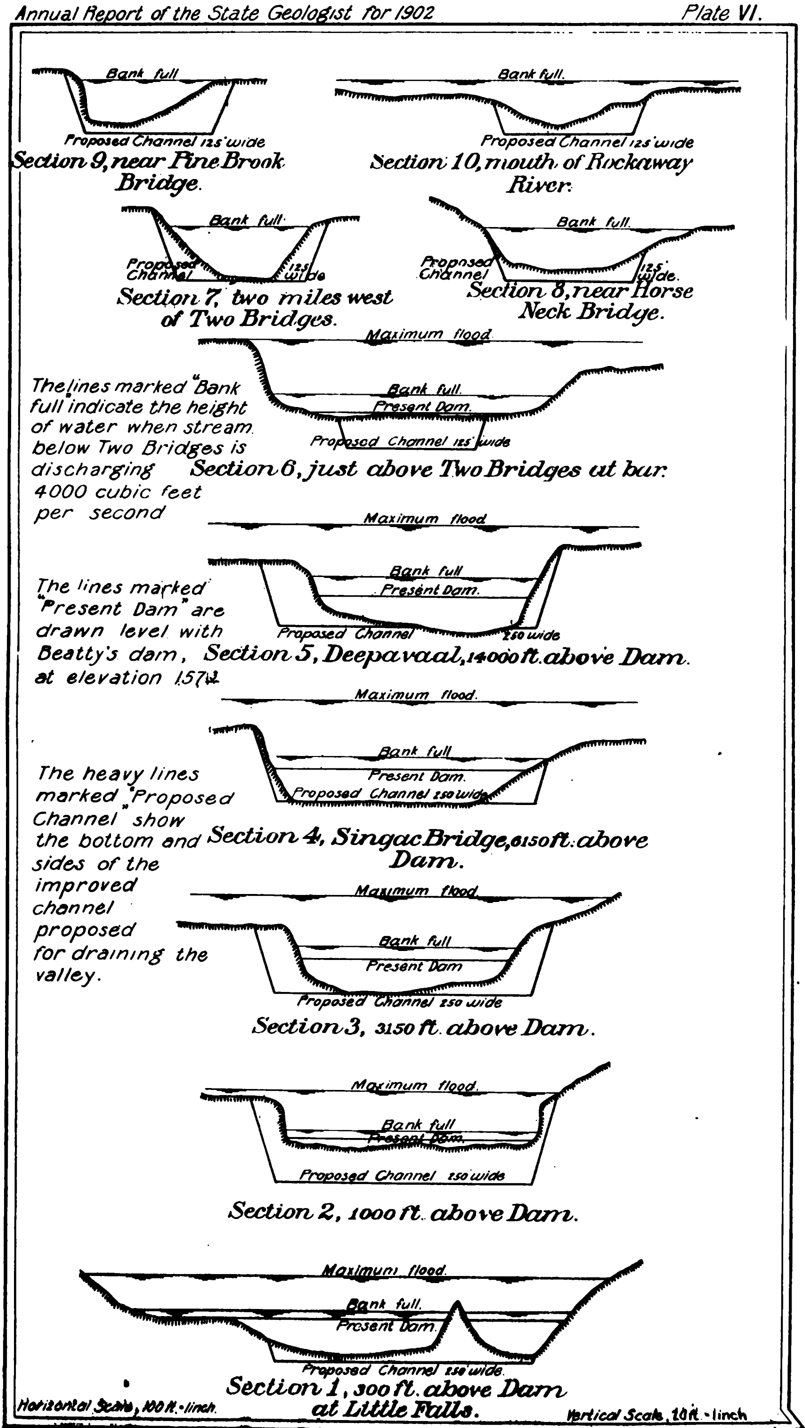
Stream discharge, in cubic feet, per second.	Elevation of surface of water at Two Bridges. Present channel.	Improved channel.
4,000	161.50	158.75
8,000	164.80	161.50
12,000	167.80	164.90
16,000	169.75	166.75
20,000	170.70	168.70
22,000	171.10	169.50

The present bank-full stage at Two Bridges is 4,000 cubic feet per second, and the table shows that for this discharge the elevation of the water will be reduced by the improvement of the channel from its present height of 161.50 to 158.75, or nearly

Plate V.



PROFILE OF PASSAIC RIVER, TWO BRIDGES TO LITTLE FALLS, SHOWING PRESENT CHANNEL, SLOPE OF WATER AT VARIOUS STAGES AND PROPOSED IMPROVEMENT.



CROSS-SECTIONS OF PASSAIC, LOOKING UPSTREAM

3 feet. With the improved channel, when the water reaches elevation 161.50 it will be discharging 8,000 cubic feet per second, or just double what it now discharges at that height. For all stages of the river up to 16,000 cubic feet per second, the height at Two Bridges would be reduced by the improvement about 3 feet, whereas at the maximum flood discharge the reduction would be only the difference between 171.10 and 169.50, or 1.6 feet.

It may be well to urge in this connection that the real benefits of the proposed drainage improvement do not depend on entirely preventing the overflow of the flat lands in time of great freshets. Such prevention would be not only financially impracticable and dangerous to Paterson, but it may be doubted if it would be entirely desirable for the lands. They are considerably enriched by the sediment deposited at such times. A lowering of the water surface at Two Bridges 3 feet during stages between 3,000 and 8,000 cubic feet per second would be of very much greater benefit than the prevention of overflow by occasional high freshets. Data recorded in the Report on Water-Supply show that the stream is between these stages, on the average, over six weeks of each year, while it exceeds 8,000 cubic feet per second less than four and one-half days each year. For weeks and months these lands are now saturated, not by extreme floods, but when the stream is slightly swollen, or during the tardy discharge of the waters at the end of a freshet, and it is this condition which causes sourness, prevents the raising of useful crops, and produces malarial or miasmatic diseases. The lowering of the river 3 feet during such times would almost entirely remove these serious blights from the Central Passaic Valley.

The profile of the river, Plate V., shows plainly that at the higher flood stages Beattie's dam is not a controlling point. It will be noted that the steep flood slope extends a distance of 4,000 feet above the dam, and the observed height, together with a computation at the cross-sections, made by means of the Kutter formula, show that this control rests with the entire channel, from the dam up to Two Bridges, but is especially affected by the reefs and constricted channel between Singac and the dam. Indeed, for the higher flood stages, Beattie's dam could be entirely removed without causing any appreciable difference in the height of the floods or the maximum discharge of the river.

It was intended by the Drainage Commissioners to put flood-gates in the dam, and one of the questions investigated by the Committee on Drainage of the Geological Survey was the proper size of these gates and their effect. The result of careful computation showed that a capacity of flood-gates in excess of 4,000 cubic feet per second would be useless, and that even with the improved channel the height of floods at Two Bridges would not be affected to any practicable extent by the existence of such gates. At the higher flood stages the discharge would be controlled entirely, even after improvement, by the capacity of the channel from Two Bridges to Little Falls. The effect of such gates, however, would be very beneficial at lower stages of the river, keeping the water level at Two Bridges lower at times when the meadows are now soured by deficient drainage, although not actually submerged by floods.

Since the rate of discharge of the main stream depends entirely upon the height at Two Bridges, whether the channel be improved or not, the question whether the proposed improvement will increase the flood discharge will be determined by ascertaining if, after improvement, the waters at Two Bridges will rise high enough to produce a discharge greater than the present maximum. By referring to Plates II. and III., which show the movement of the floods of 1896 and 1902, the reader will be enabled to follow the reasoning on which we base our conclusions that no such increased flood discharge can occur. We have seen in our analyses of the several floods that the maximum discharge of the Pompton, at Two Bridges, is reached usually about 33 hours earlier than the maximum of the main stream below Two Bridges, and that the channel below Two Bridges is at present insufficient to carry off the Pompton waters as fast as they come down to Two Bridges, so that these waters are held back and driven up stream into Great Piece meadow to augment the flood-waters coming down from the southerly branches. The improved channel, because of its greater capacity, will carry off a larger volume of these Pompton waters during the early hours of the flood, and thereby decrease the accumulation of water on Great Piece meadow, making it impossible for the water to rise as high at Two Bridges after, as it does before improvement.

Take for illustration the flood of 1896, Plate III. On this

diagram we have shown by line "d" the curve of estimated discharge of the Passaic after improvement, in accordance with the assumed maximum possible improvement of the river. This curve shows that by midnight of February 7th the improved discharge would have exceeded the discharge of the old channel by 589,000,000 cubic feet, which represents nearly one-third of the entire volume of waters accumulated on the flats during that flood. By midnight of February 6th, the discharge of the old channel had reached 10,600 cubic feet per second. We may assume that after improvement the waters at Two Bridges would reach the same elevation as before, owing to the rapid influx of Pompton water, because at this stage the river would then spread but little beyond its banks. The discharge of the new channel would then be 15,500 cubic feet per second. Now, the measured discharge of the present channel (line "a," Plate III.) shows that when it had reached this stage of 10,600 cubic feet per second, corresponding to elevation 166.9 of water surface at Two Bridges, the main stream began to subside, continuing to do so for seven hours. This subsidence was clearly due to the fact that the waters from the southerly branches could not get down across Great Piece meadow fast enough to maintain a flow of 10,600 cubic feet per second on the lower stream; and consequently, to maintain the improved discharge of 15,500 cubic feet per second, a very considerable improvement of the river channels above Two Bridges will be necessary. We have assumed in our estimates that the improvement will be carried out to a sufficient extent to maintain this discharge. Now, this line "d" shows that by midnight of February 7th the new channel would have discharged 589,000,000 cubic feet more than the old channel. Consequently, as the total accumulation during that flood did not exceed 1,880,000,000 cubic feet, it would have been diminished over 30 per cent. This would have so reduced the height of the water above Two Bridges as to make it impossible for the stream to exceed a maximum of 15,500 cubic feet per second, and we estimate that by 4 A. M. of the 8th it would have begun to decline, as shown by line "d" of Plate III. A reference to line "e," showing the estimated discharge of the Upper Passaic at the same time, indicates that under the new conditions of improved channel these waters will come down a little more promptly at

first, as they are not held back to the same extent by the rush of waters from the Pompton, which are now carried down stream, but they reach their maximum discharge at about the same time as before.

The bank-full stage before improvement was 4,000 cubic feet per second, but after improvement this is increased to 8,000 cubic feet per second, so that the period during which the stream is out of its banks at Two Bridges will be reduced for such a flood as this from 150 hours to only 90 hours. Not only will this period of overflow be thus shortened by 60 hours, but the stream will promptly subside still lower and the flats will dry up.

Taking the diagram of the flood of 1902, Plate II., we estimate that the rise of the stream after improvement will not differ materially from that observed for the present channel, as shown by line "a," until the discharge has reached 12,000 cubic feet per second, because during that period the rise of the Passaic was uniform and controlled by the steady swelling of the several branches, which had not yet begun to rise in a violent manner; but from that time forward the discharge by the new channel, shown by line "d," would have been accelerated more rapidly than with the old channel, because of the rapid rise of the Pompton, and, by 6 A. M. of March 1st, we estimate that it would have reached 21,000 cubic feet per second. Continuing at this rate until noon of the 2d of March, it would have disposed of 569,160,000 cubic feet of the waters accumulated on the flats, or about one-third of the whole; consequently, it would have been impossible for the stream to rise at Two Bridges as high as it did before improvement. We estimate that it would not have increased above 21,000 cubic feet per second, but with adequate improvement of the upper channel it would have been maintained at about this rate until 10 A. M. of the 3d, after which it would steadily decline. It will be noted that during this flood, after improvement, the flow of the Pompton is taken care of as fast as it comes down, and that the waters from the southerly branches, or the Upper Passaic, the discharge of which is shown by line "c," will consequently come down more rapidly at the start, but are estimated to reach a maximum discharge almost as great and at about the same time that it actually occurred with the existing channel, as shown by line "c," after which

there will be a steady decline as the waters are discharged from the flats.

It may be thought that the fact that the water at Two Bridges would be maintained at a lower level after improvement, should cause a greater slope of the water surface through Great Piece meadow, and consequently an accelerated discharge of the waters of the Upper Passaic; but it will be found that the reduction of depth over the flat, and consequent reduction of the hydraulic mean radius, will effectually prevent any such acceleration, and that consequently a very considerable improvement of the upper channels will be absolutely essential to maintain the flow at even as high a stage as we have estimated.

The result of our earlier studies, confirmed by the history of the floods of 1896 and 1902, indicate clearly, therefore, that any drainage of the wet lands which is financially practicable, or which is necessary and desirable, can be carried out without increasing, but actually decreasing the rate of discharge of floods on the lower river. In order to emphasize the impracticability of any scale of improvement which would imperil the lower river, it may be well to point out that the cost of an improvement on a scale which we have assumed in the above studies would be, for the work below Two Bridges alone, \$192,500, while in order to make this improvement effective above Two Bridges it would be necessary to spend at least enough more to bring the total up to \$250,000, a sum which is far more than the Drainage Commission has ever contemplated. While an improvement to this extent would be entirely safe and desirable, a more moderate scale of works could nevertheless be made effective and useful.

CONTROL OF PASSAIC FLOODS BY STORAGE.

A plan for controlling the floods of the Passaic by storage might be worked out in such a manner that it would at the same time confer other marked benefits, such as, first, converting the unhealthy flat lands of the valley into lakes, thereby eliminating the drainage question entirely; second, providing a larger summer flow of the main stream through Paterson and Newark, and a means of thoroughly flushing the same by artificial freshets,

thereby removing the sewage nuisance; and third, maintaining and improving the valuable water powers at Little Falls, Paterson and Dundee, thereby adding to the prosperity of those places. If large reservoirs should be created, flooding the 20,000 acres of wet lands which it has been proposed to drain, they might be rendered as innocuous as if drained, and the picturesqueness and desirability of the valley greatly enhanced. With properly designed spillways and flood-gates, all floods, even so great a one as that of 1902, could be kept down to the very harmless discharge of 12,000 cubic feet per second, a diminution of over 40 per cent., and such flood control need not cause a variation in the level of such reservoirs exceeding 3 feet. Finally, a draught of 8 feet on such reservoirs would maintain the summer flow of the river, at all times, at 440,000,000 gallons daily, or four times the present summer discharge. Such a flow as this, aided by an occasional flushing by a higher rate of discharge for 24 or 48 hours, would unquestionably greatly mitigate the present evils arising from the discharge of sewage into the lower stream, and might postpone for many years the necessity of expending a large amount of money, estimated at much over $7,000,000, in the construction of the trunk sewer which is now proposed. In proof of this proposition we have only to cite the absence of any serious nuisance during wet seasons, when the stream does not run low.

Such an increase of the summer stage of the river would, moreover, afford additional water-power at Little Falls, Passaic and Dundee, amounting in all to 10,240 gross horse-power day and night, or over 20,000 horse-power for 12 hours daily, which would be worth, at the rates obtained for water-power at those places, $600,000 annually, which, capitalized at 6 per cent., would indicate a value of $10,000,000 for these reservoirs for this purpose alone.

Such a system of reservoirs might be so planned that they would in nowise interfere with, but would add to the value of the stream for municipal water-supply.

To sum up the advantages of such a system of reservoirs, therefore, we should substitute for 20,000 acres of malaria-breeding wet lands an equal area of water-surface, which would greatly enhance the beauty and attractiveness of the Passaic

Valley; we would control such great floods as that of 1902 to an extent which would do away with all damage along the lower stream; we would indefinitely postpone an expenditure of probably not less than $10,000,000 for the construction of a trunk sewer and sewage disposal works on the lower stream; and finally, we would create additional water-power, worth $10,000,000, for use in manufacturing or for other purposes, thereby giving a fresh impetus to the growth and industrial prosperity of Paterson and Passaic and greatly adding to the wealth of the State.

To be sure, the interests affected, public and private, are varied, and the plan could not be made practicable and effective without giving proper consideration to all, but the advantages to all these interests certainly seem to be sufficiently great to make it worth while to give it the careful consideration and to bring about the broad co-operation which will be necessary to its success.

RARITAN CATCHMENT.

At the Delaware and Raritan canal dam, below Bound Brook, it was impossible to compare the flood-heights of 1902 with those of previous freshets, owing to the fact that the dam was washed out early in the year, before the occurrence of this flood, but from notes obtained on the upper stream it is clear that while the total run-off during the flood was very great in volume, the maximum discharge of the stream was less than in 1896. None of the branches of the Raritan reached so high a stage as in 1896, excepting the upper Millstone river. This, being a stream of low maximum, coming from a flat country, appears to agree with other streams of this class, such as the lower Passaic and Pequest, in having reached a greater height than in 1896.

At Rocky Hill the flood is said to have been the highest since 1882. At Griggstown it was 5¼ feet lower than in 1882, but about 5 inches higher than in 1896. At Blackwell's Mills the present flood was 2 feet 2 inches lower than in 1896, and 6 feet 2 inches lower than in 1882.

4

On the south branch of the Raritan, at South Branch village, the height was the same as in 1896. The following table shows the relative height above sea level of several freshets since 1850, as indicated by flood-marks in the mill at South Branch:

Relative height of floods at South Branch.	Elevations above sea level.
July 29th, 1897	57.23
March 19th, 1896	58.89
August 4th, 1885	58.96
July 23d, 1887	59.43
July 31st, 1889	59.52
February 11th, 1886	59.66
September 23d, 1882	59.96
September 2d, 1850	60.54
July 17th, 1865	60.54
February 6th, 1896	62.27
March 1st, 1902	62.27

The ordinary summer level of the river is at elevation 49.0. It should be noted that the height of the freshet at South Branch does not necessarily represent the relative rate of discharge at the maximum, but may be due to the accumulation of the waters of the north and south branches more rapidly than they can be discharged by the main stream below the confluence.

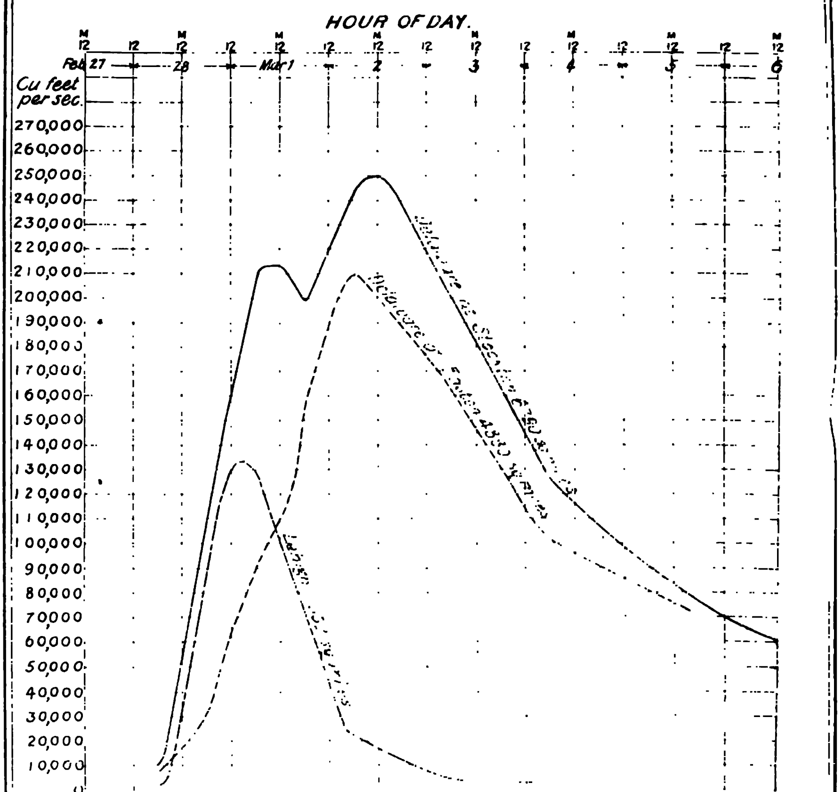
At Neshanic the freshet was 3 feet 2 inches lower than in 1896. Marks in the mill give the following heights of the several floods:

February 6th, 1896	76.79
September 23d, 1882	74.94
1869	74.58
1850	74.04

At High Bridge the water was about 2 feet lower in the dam than in 1896, which makes the rate of discharge not much more than one-half that of 1896.

DELAWARE CATCHMENT.

At Stockton, the Delaware began to rise on February 28th, at 7 A. M., and continued rising quite uniformly until 6:30 A. M. of March 1st, when it reached a discharge of about 213,000 cubic



APPROXIMATE CURVES ... OF
THE DELAWARE ... -
ES FEB. 27 ...

feet per second. After this it remained nearly stationary for two hours and then subsided gradually until after 6 P. M of the 1st, when it again began to rise, reaching a maximum of about 250,000 cubic feet per second at noon of March 2d, after which it declined quite steadily, until on the evening of the 6th inst. it reached about the same height as when it began to rise. At its highest it was 4 inches lower at Centre Bridge than the flood of 1841, and at Lambertville bridge it was 9 inches lower. On the upper Delaware, at Easton, the freshet of 1862 was also a little higher than that of 1902, but it was two feet lower at Centre Bridge. The height of the flood of 1902 above ordinary low-water at Trenton was 16.6 feet, at Lambertville it was 19.2 feet, at Centre Bridge, or Stockton, 25 feet, at Easton 32 feet, and at Belvidere 22 feet. The accompanying diagram, Plate VII., shows the approximate curves of discharge of the Delaware at Stockton, the Delaware above Easton, and the Lehigh, respectively. It will be seen that the first maximum of the lower Delaware was due to the rush of water from the Lehigh and other lower branches, while the second maximum was caused by the waters of the upper Delaware.

While the Delaware did not reach the height of the great flood of 1841, the volume of the run-off during the flood of the present year was very great, as it was on other streams. An approximate computation shows that during eight days the river discharged at Centre Bridge a total of 77,930,600,000 cubic feet, which equals 4.91 inches of rainfall on the catchment. We have seen that during the same period the Passaic discharged a quantity equal to 5.35 inches of rainfall.

An interesting record of heights of Delaware floods was furnished by Mr. B. M. Youell, who lives near the bridge at Phillipsburg and Easton. This record was kept at Snyder's tannery, at the foot of North Third street, in Easton, from 1777 to 1814. From 1814 to 1841 there is a break, and then, beginning with the great flood of 1841, the record has been kept at Delaware bridge. Combining this record with the records published in the Report on Water-Supply of 1894, we have the following exhibit:

FLOODS ON THE DELAWARE.

Name.	Date.	Height in feet. Lambertville.	Height in feet. Easton.
	October 27th, 1777	....	23.2
	May 9th, 1781	....	25.5
	February 29th, 1783	....	24.4
	March 17th, 1785	....	26.9
Pumpkin Fresh	October 4th-6th, 1786	16	25.2
	1798	less than '86	....
Jefferson Fresh	1801	14	....
	April 1st, 1814	14	24.5
	March, 1832	12	....
	April, 1836	14.5	....
Great Flood	January 8th, 1841	20	32.2
	October 13th, 1843	14	....
	October 13th, 1845	....	22.7
	March 15th-16th, 1846	17.5	27.7
	March 3d, 1857	....	24.3
	July 20th, 1860	....	24.7
June Fresh	June 3d-8th, 1862	18	32.1
October Fresh	October 15th, 1869	....	28.7
	December 11th, 1878	....	28.7
	October 21st, 1879	....	22.8
	March 2d, 1882	....	23.5
	April 14th, 1885	....	21
	February 14th, 1886	....	23.2
	April 1st, 1886	....	21.2
	June 6th, 1886	....	20.2
	September 18th, 1888	....	22.1
	March 12th, 1893	....	21
	April 9th, 1895	....	27.5
	February 6th, 1896	....	28.7[a]
	March 1st, 1896	....	20
	March 2d, 1900	....	18
	March 1st-3d, 1902	19.2	32

[a] February 6th, 1896, freshet about the same at Belvidere as 1869. Assume same at Easton. No record.

It is interesting to note that the record from 1777 to 1786 shows five freshets exceeding 23 feet rise at Easton during a period of ten years, whereas there is no later period of ten years which shows so many of equal height. Although the record is not complete, this fact appears to throw some doubt on an oft-repeated assertion, to which we have given some credence, viz.: that great floods on the Delaware are more frequent than they were formerly.

The Musconetcong did not reach as great a height as in 1896. At the Warren Paper Mills the maximum was 3,300 cubic feet per second on March 1st, 1902, whereas on February 6th, 1896, it was 4,410 cubic feet per second. At Saxton Falls the maximum was 2,094 cubic feet per second, while in 1896 it was 2,295 cubic feet per second. At Lake Hopatcong the total volume of water discharged into the lake from the catchment amounted to 3.99 inches in 60 hours.

On the Pequest, at Belvidere, a much greater height was reached than during any previous flood during the last 30 years, and the discharge amounted to 2,959 cubic feet per second. This is said to be the highest for this stream since 1862, 1857 having been still higher.

On the Paulinskill, at Paulina, the discharge during the present year amounted to 2,230 cubic feet per second, being much lower than in 1896. Conditions on this stream are somewhat similar to those on the lower Passaic, the streams being bordered by extensive flats.

The Crosswicks creek, near Crosswicks, did not reach an unusual height. In fact, of the Southern New Jersey streams, none equaled the record of 1882. These streams do not usually reach their greatest height during the winter and spring floods, as the snow does not accumulate on the ground to the same extent that it does in Northern New Jersey.

General Conclusions.

Our records of this flood, together with additional data collected for the previous floods, lead to, or confirm the following conclusions:

1. The data do not indicate either increased height or increasing frequency of high freshets during recent years.

2. Since such great floods as those of 1896 and 1902 are largely due to the presence of accumulated ice and snow, and since forests tend to increase such accumulations by shading the earth, such freshets cannot be prevented by forestation. That greater or less amounts of forest cover upon the catchments did

not appreciably affect the flood-discharge of the several streams of similar topography, was shown in the report upon the flood of 1896.

3. Topography and soil, the degree of saturation of the soil, and the rate of precipitation are the principal and probably the only factors in determining the rate of flood-discharge. The rate of precipitation must be determined by including melting snow and ice.

4. The maximum rate of discharge and the volume of run-off have no necessary relation to each other on precipitous catchments, but upon streams bordered by flats they increase or decrease together.

5. Having in the flood of 1882 a summer freshet of a high rate of discharge, with moderate suddenness and ordinary volume of run-off; in the flood of 1896 one of extreme suddenness and high rate of discharge, with small volume of run-off; and in that of 1902 a flood of comparative slowness of rise, with moderate rate of discharge, but very great volume of run-off, our experience embraces a wide range of conditions from which much may be learned as to the regimen of the rivers. The flood-marks of the past indicate that equally great floods have occurred, and on the Passaic even greater ones. There will be no good reasons for surprise if they occur again. Encroachments upon the water-way of the streams, made without regard to these flood-marks, must inevitably result in loss of property if not of life.

REVISION OF RECORDED MAXIMA.

Since the highest floods of which we had record, at the date of preparation of the Report on Water-Supply of 1894, have been exceeded on most of the streams either in 1896 or 1902, it becomes necessary to revise our figures of maximum discharge given on page 103 of that report. This we have done in the following table:

MAXIMUM FLOOD DISCHARGE.

Stream.	Place of observation.	Area of catchment. Square miles.	Maximum discharge in cu. ft.	Maximum discharge in cu. ft. per sq. mile.	Date and remarks.
Ramapo	Pompton	159.5	10,540	66.1	Sept. 22d, 1882.
Wanaque	Pompton	73	7,203	99	Feb. 6th, 1896.
Pequannock	Pompton	48	5,500	115	Feb. 6th, 1896.
Rockaway	Pt. Oram	29.9	1,997	67	Mar. 1st, 1902.
Rockaway	Dover	52.2	2,250	43	Sept., 1882.
Rockaway	Boonton	118.9	5,445	46	Feb. 6th, 1896.
Whippany	Whippany	38	3,200	84	Feb. 6th, 1896.
Pompton		285	......	76	Feb. 6th, 1896.
Passaic	Little Falls	772.9	21,207	27.4	Mar. 2d, 1902.
Passaic	Dundee	822	22,677	27.6	Mar. 2d, 1902.
Passaic	Little Falls	772.9	25,500	33	Estimated for flood of 1810.
Raritan	Bound Brook	879	59,500	68	Feb. 6th, 1896.
Raritan, South Branch	South Branch	276	......	100	Estimated for Feb. 6th, 1896.
Raritan, South Branch	High Bridge	67	7,558	113	Feb. 6th, 1896.
Raritan, North Branch	Milltown	192	......	100	Estimated for Feb. 6th, 1896.
Raritan, North Branch	Pottersville	33	......	80	Estimated for Feb. 6th, 1896.
Dumont's Brook,	North Branch	10.5	......	140	Estimated for Feb. 6th, 1896.
Delaware	Stockton	6,790	254,643	37.5	1841.
Delaware	Easton	4,880	215,000	44.5	Estimated for Mar. 2d, 1902.
Lehigh	Easton	1,332	......	55	Estimated max.
Musconetcong	Riegelsville	132.2	5,692	43	Feb. 6th, 1896.
Musconetcong	Saxton Falls	31	2,295	64	Feb. 6th, 1896.
Lopatcong	Lower Harmony,	3	......	133	
Pequest	Belvidere	158	2,959	18.7	Feb. 6th, 1896.
Pequest	Tranquility	34.8	650	18.7	
Paulinskill	Paulina	126	6,734	54	Feb. 6th, 1896.
Swartswood Lake		16	1,070	65.8	
Great Egg Harbor	May's Landing,	215.8	4,756	22	Maximum.

The above drainage areas are corrected by deducting areas tributary to reservoirs which retained the flood-flow.

There are several formulæ given for computing the maximum discharge of streams, which are used to greater or less extent by engineers. A number of these are quite complicated. It seems desirable to reduce them to the simplest possible terms, from the fact that good judgment and experience in applying such formulæ to a given water-shed are extremely important, and this may be lost sight of in the application of elaborate formulæ. Such a thing as mathematical accuracy is impossible, owing to the infinite variety of conditions presented by different water-sheds. The formula given by Fanning for flood-discharge which may be anticipated upon the average New England and Middle States basins, is as follows: $Q=200\ M^{\frac{5}{6}}$, in which $Q=$ discharge in cubic feet per second, and $M=$area of catchment in square miles. Given a certain type of catchments, this formula seems to express very well the law of variation in discharge due to varying size of catchment. It is a good basic formula, but needs the addition of a coefficient varying with the topography of the catchment. It gives quite accurate results, without correction, for the following New Jersey streams: Dumont's brook, Lopatcong creek, Wanaque, Pompton, Delaware at Stockton, Delaware above Easton, and Lehigh, these water-sheds ranging in size from 3 to 6,790 square miles. For the other streams of which we have record the results of this formula must be multiplied by the following coefficients: 1.25 for the North and South Branches of the Raritan at their confluence; 1.10 for the Pequannock, the main stream of the Raritan and the South Branch above High Bridge; .8 for the Whippany, Ramapo and North Branch of the Raritan above Pottersville; .7 for the Rockaway above Port Oram, Upper Musconetcong and the Paulinskill; .6 for the Rockaway at Boonton, and the Passaic at Little Falls and Dundee; .5 for the Musconetcong at Riegelsville, and the Rockaway at Dover; .3 for the Great Egg Harbor and other streams of Southern New Jersey with flat, sandy water-sheds; .2 for the Pequest. It will be observed that there is a wide range of coefficients. The higher ones apply to streams where there is but a small amount of flat lands along the banks and where the slope of the stream is rapid, while the lower coefficients apply to streams having broad bordering flats and a low rate of slope along the axis of the stream. Rivers

like the Raritan, having a number of important branches converging to nearly the same point, have high coefficients as compared with streams having only small branches evenly distributed along its course, such as the Paulinskill or Musconetcong. The choice of a coefficient can be most judiciously made by comparing the catchment with those above named, being sure to select a value high enough.

PART II.

Report on Artesian Wells.

By LEWIS WOOLMAN.

Artesian Wells.

OUTLINE.

INTRODUCTION.

WELLS IN SOUTHERN NEW JERSEY.

Artesian Wells.

INTRODUCTION.

The writer presents this year data respecting such wells in the Coastal plain portion of New Jersey as time from other important duties has permitted him to collect and study. The records, though not so numerous as in past years, include wells at two localities, viz., Hammonton and Cape May, where accurate and reliable information has been most needed in order to work out satisfactorily the underground structure of Southern New Jersey.

The borings at Hammonton, while they have given much information down to the depth of about 300 feet, were, unfortunately for the geologist, not sufficiently deep to reveal entirely the structural relations of these beds with those of districts both to the east and the west at lower elevations. Had one of the borings at this point been continued from 50 to 150 feet further we should probably have had the data which would permit the construction of a vertical section southwest across the State from the Delaware river to the Atlantic ocean. Such a section would be approximately near the line of the railroads from Philadelphia to Atlantic City. Its construction, however, will have to be deferred for the present.

At Millville, where one deep well and a few shallower ones were reported last year, a considerable number of additional wells, to depths ranging from 66 to 191 feet, have been put down. From these we have gained information as to the probable relations of the upper series of beds here and at other points in Southern New Jersey. The probable correlation of the various beds penetrated is noted in the records of the wells at Millville and Hammonton.

The wells are arranged on the following pages in geographical rather than in geological order.

WELLS IN SOUTHERN NEW JERSEY.

ARTESIAN WELL AT WARETOWN.

**Elevation, 8 feet; diameter, 2 inches; depth, 100 feet.
Water rises 12 feet above the surface and overflows 9 gallons per minute.**

Drilled and reported by Thomas Roberts.

This well was put down about five years ago. The water-supply was found in a "white gravel" at 100 feet from the surface. Hard clay, light in color, is reported between the depths of 35 and 45 feet, below which were "soft black sands and clays." The location, we are informed, is about three-fourths of a mile west of a well recorded in the Annual Report for 1892, page 293, as having been sunk to the depth of 280 feet. Water was then reported as having been found and passed in the process of drilling at the depths of 70 and of 137 feet.

In the clays procured at that time by the writer from the dump around the mouth of this earlier well, marine diatoms characteristic of the great diatomaceous clay-bed of the Miocene period were found.

WELL AT ISLAND BEACH, SOUTH OF SEASIDE PARK.

Elevation, 10 feet ±; diameter, 2 inches; depth, 73 feet.

Thomas Roberts, who drilled this well, furnishes the following facts respecting it:

Mud bed 8 inches thick between the depths of	12	and	13	feet.
Mud bed 18 inches thick between the depths of	21	"	23	"
Oyster-shell bed 1 foot thick between the depths of	34	"	35	"
Mud bed 18 inches thick between the depths of	35	"	37	"
Reddish sand was entered at			60	"
Coarse white water-bearing sand was found at			73	"

ARTESIAN WELL AT BARNEGAT PIER.

**Elevation, 1 foot ±: diameter, 2 inches; depth, 58 feet.
Overflows 1 foot above the surface.**

Drilled and reported by Thomas Roberts.

This is a flowing well and was sunk at F. Sutton's on the meadows on the south side of Toms river, near where that stream

enters Barnegat bay. The water-horizon opened by this well is thought by the driller, Thomas Roberts, to be the same as that developed by the well at Island Beach at the depth there of 73 feet (see the preceding record).

SHALLOW ARTESIAN WELL AT CHADWICK.

Elevation, 10 feet ±; diameter, 2 inches; depth, 79 feet
Water rises 8 inches above the surface.

Well drilled and data furnished by Thomas Roberts.

This locality is on the strip of beach land between Barnegat bay and the ocean. The well is about six miles north of Seaside Park, and also about six miles northeast from Island Heights, which place and Chadwick are nearly upon the line of strike of the underlying Miocene and Cretaceous formations.

By request of the owner, Theodore W. Stemler, a series of the borings were courteously furnished the Survey by the contractor. From an examination of the same, both microscopically and otherwise, we present the following record:

Soil and meadow muck	surface		to	5	feet.
Beach sand somewhat muddy	5	feet	to	22	feet.
Sand	22	"	"	25	"
Mollusks, viz., *Mytilus edulus* and *Pecten irradians*, at				25	"
Dark sandy clay, contains *sponge spicules* and *diatoms* of species the same as those now living along the coast	25	"	"	27	"
Mixture of coarse sand and medium coarse gravel	27	"	"	31	"
Clay, dark in color and somewhat micaceous	31	"	"	35	"
Mollusks, *i. e. Pecten*, at				35	"
Clay, containing no micro-organisms	35	"	"	45	"
Sand	45	"	"	46	"
Clay with no micro-organisms	46	"	"	54	"
Sand	54	"	"	58	"
Gravel mixed with sand	58	"	"	60	"
Coarse white gravel	60	"	"	68	"
Coarse sand with water	68	"	"	74	"
Sandy clay, no micro-organisms	74	"	"	79	"

This well, though drilled to the depth of 79 feet, was finished at 74 feet, the depth at which water was found.

ARTESIAN WELL AT BAYHEAD.

Elevation, 10 feet; diameter, 6 inches; depth, 870 feet. Water overflowed 100 gallons a minute.

Kisner & Bennett, who drilled this well, furnish the above data and the following record which we quote nearly verbatim, inserting, however, two intervals they did not describe, and adding our interpretation of the geology on the right:

Sand surface to	125 feet.		Recent and Miocene.
Rotten stone	125 feet to 200 "	Miocene clay	
Sands same as in Island Heights well	200 " " 225 "		Age?
Marl	225 " " 325 "		Probably Eocene in part.
Very white marl, came out with the (wash-out) water just like milk	325 " " 400 "	Ash marl	Cretaceous.
Greensand marls	400 " " 659 "	Middle and lower marl beds	
Yellowish sand, flowed a nice stream of water, the same as at 400 feet at Asbury Park	659 " " 690 "	Sand at the top of the clay marls. Marlton water-horizon	
Clay marls	690 " " 780 "	Clay marl	
Sands in the middle of the clay marls, *water bearing,*	780 " " 870 "	Cropwell water-horizon	

This is the third well that has been sunk at or near Bayhead. The two former ones had depths of 885 and 813 feet and were recorded in the Annual Report for 1896, pages 151 and 152. This well has a six-inch casing to the depth of 225 feet to the top of the marl series, and was continued below this with a four-and-a-half-inch casing to the depth of 780 feet. The drilling was continued below the casing in water-bearing sands to the total depth named above of 870 feet. The horizon developed is the equivalent of that at about 550 feet at Asbury Park.

THREE SHALLOW ARTESIAN WELLS AT FARMINGDALE.

Depth of one well, about 40 feet below the bottom of the marl-pit. Depths of two wells, 68 and 87 feet below the surface of the ground.

Among our heretofore unpublished data we find notes, made at an interview some years ago with Uriah White, that a well about 40 feet deep had been sunk from a level near the lowest part of the cartway sloping to the bottom of one of the marl-pits at Farmingdale, and that this well passed at its base through 4 or 5 feet of material which he described as "coral."*

Uriah White also at the same time informed us that at a powder factory, about one mile northeast of the above well, there had been sunk two wells to the depth respectively of 68 and 87 feet.

All three of these wells probably reached the same water-horizon.

ARTESIAN WELL AT SEA GIRT.

Elevation, 15 feet; diameter, 6 inches; depth, 750 feet. Water overflows at the surface 28 gallons per minute.

Drilled and data furnished by Kisner & Bennett.

The above well is on the camp-ground at Sea Girt. The water-horizon corresponds with that at the depth of 550 feet at Asbury Park, and is probably the equivalent of that which we have named in Burlington county, the Cropwell water-horizon. It occurs about 175 feet beneath the top of the Clay Marls and is situated well within that formation.

In the Annual Report for 1895, page 75, we recorded a well put down at Sea Girt to the depth of 755 feet, the water-bearing stratum occupying the interval between the depths of 735 and 755 feet. This well doubtless draws from the same water-horizon. For a detailed record of the various beds penetrated the reader is referred to the Annual Report for 1895.

*** These are probably the Bryozoan-bearing beds of the limesand.—H. B. K.**

ARTESIAN WELL AT KEY EAST.

Elevation 10 feet; diameter, 3 inches; depth, 430 feet.

Drilled by Kisner & Bennett, at Hotel Avon.

This well was very briefly reported in the Annual Report for 1885, page 130, but without any stratigraphical notes. More recently the contractors have furnished the following record of beds penetrated:

Sand and coarse gravel	2 feet	=	2 feet.
"Rotten stone," brown	35 "	=	37 "
Fine light sand	5 "	=	42 "
Whitish clay	10 "	=	52 "
Quicksand, gray	40 "	=	92 "
"Rotten stone," brown	20 "	=	112 "
Coarse sand	8 "	=	120 "
Marl	300 "	=	420 "
"Oyster" shells probably at about 400 or 420 feet.			
Yellowish sand	10 "		430 "

This locality is on the beach north of the mouth of Shark river. On a test this well gave 52 gallons a minute. By comparison of the above record with other wells along the coast and in the interior to the southwest, we conclude that this well reaches the Marlton water-horizon, and corresponds with the depth of 380 feet at Asbury Park.

THREE SHALLOW BORED WELLS AT NORTH SPRING LAKE.

Depth, 47 feet.

These wells were put down in 1891 and are east of the railroad. Kisner & Bennett, who drilled them, furnish the following record:

Soil and white sand, then blue clay to the depth of	27 feet.
Yellow sand	from 27 feet to 47 "

ARTESIAN WELL AT LONG BRANCH.

Elevation, 10 feet; depth, 371 feet.

Among our heretofore unpublished data we find a note that a well was drilled in 1894 by Uriah White, at Long Branch, to the depth of 371 feet. This well is supplied by the same water-horizon as that at the depth of 550 feet at Asbury Park.

ARTESIAN WELL AT DEAL.

Elevation, 20 feet ±; diameter, 6 inches; depth, 112 feet.
Overflows at the surface 300 gallons per minute.

Drilled and reported by Kisner & Bennett.

This well was put down on the shore of Whale Pond brook, about two miles inland from the ocean and near the old town of Deal proper. The location is also about two miles northwest of Deal Beach and one mile west of Elberon.

Kisner & Bennett regard the finding of a strong water-bearing sand in this region, at the comparatively shallow depth of 112 feet, as remarkable. The yield also is certainly phenomenal. This well is probably supplied from the "Yellow Sands" or the underlying limesands.

ARTESIAN WELL AT MATAWAN.

Elevation, 10 feet ±; depth, 205 feet.

Kisner & Bennett report sinking a well for the town supply at Matawan. They found a water-bearing sand between the depths of 185 and 205 feet. This water-horizon occurs well within the Raritan group of sands and clays.

TWO ARTESIAN BORINGS IN PHILADELPHIA AT THE FIDELITY BUILDING, BROAD STREET, NORTH OF ARCH STREET.

Elevation of street, 40 feet.
Well No. 1—Diameter, 8 inches; depth, 46 feet below street level.
Well No. 2—Diameter, 10 inches; depth, 42 feet below street level.

A few years since, at the time of the erection of Fidelity Building, in Philadelphia, two wells were sunk from the floor of the sub-cellar, which floor is about 17 feet below the curb-level of the street. The record for these wells is as follows:

	Thicknesses.	Depths.
Depth to cellar floor	17 feet	= 17 feet.
Coarse loamy sand, reddish in color	12 "	= 29 "
Heavy gravel	16 "	= 45 "
Coarse white sand	1 foot	= 46 "

These wells together yield by pumping 300 gallons per minute. The natural level of the water is said to be about 3 feet below the cellar floor, or about 20 feet below the street level.

ARTESIAN WELL AT ASYLA.

Elevation, 25 feet; total depth, 457 feet; diameter, 8 inches to 190 feet; diameter, 6 inches to 475 feet.
Water rises within 25 feet of the surface.

This well was put down to supply water to the Camden County Asylum.

The sinking of this well was strongly advocated by Charles F. Currie, the Superintendent of the Asylum. With intelligent appreciation of the work of the Survey, he in advance asked our opinion as to the number of water-horizons likely to be met with and their depth. These horizons we predicted and he has since informed us that they were all found, three in number, and near the depths we had named.

The drilling of the same was done by Thomas B. Harper, through whose co-operation with C. F. Currie we have been furnished with a full series of the borings and also with some

descriptive data respecting the same. After a careful study of these borings, both macroscopically and microscopically, we present the following record:

Surface soil, contains occasional fragments of limesand rock	Surface to 5 feet.			
Greensand marl with fragments of *Terebratula*, probably *harlani* M. and other shells; also numerous *foraminifera.*	5 feet " 10 "	Middle and Lower Marl beds.		Cretaceous.
Similar greensand marl mixed with quartzose sand, contains heavier fragments of shells but no *Terebratula* and very few *foraminifera*	10 " " 20 "			
Nearly pure greensand marl without quartz grains. Contains numerous *foraminifera*	20 " " 40 "			
Sand-mixture of greensand and white quartz grains. Water bearing between 80 and 90 feet. Water rising 14 feet above the surface	40 " " 90 "	Sand. Marlton Water-Horizon.	Clay Marls.	
Black clay marl with greensand	90 " " 140 "	Clay.		
Sand	140 " " 190 "	Sand. Cropwell Water-Horizon.		
Water between 175 and 190 feet that also rose 14 feet above the surface.				
Indurated rock seam 4 feet thick that prevented sinking the 8-inch casing below 190 feet	190 " " 194 "			
Clay marl with greensand*	194 " " 220 "	Clay.		
Sand*	220 " " 312 "	Sand.		
Black clay marl*	312 " " 400 "	Clay.		
Sand	400 " " 437 "	Raritan.		
Coarse gravel with water that supplies the well	437 " " 457 "			

*The combined thickness (206 feet) of these beds is much greater than that of the two lower numbers of the clay marl group, to which they seem to belong. This may be due to the intercalation of a sand bed between the two clay beds, as seems to be the case from the record as given, or it may be that the lower black clay bed of the section belongs in part to the Raritan group.—H. B. K.

We are informed that water rose from below 440 feet to "exactly 25 feet from the surface," that is, to about tide level. This is in keeping with our information elsewhere, as at Camden, Gloucester, &c., where the water from wells sunk to the top of the Raritan beds, and indeed still deeper within them, generally rises only to about the level of tide-water. In this connection, it should be observed that, as stated in the above record, the water from the two higher horizons, viz., the Cropwell and the Marlton water-horizons, rises some 14 feet *above* the surface, or about 40 feet higher than that from the Raritan beds.

C. F. Currie wrote that "with a 4-inch pump worked by the driller's engine the well produced 100 gallons a minute." He also stated that the water is soft and apparently satisfactory, although no analysis had then been made.

NINE ARTESIAN WELLS NEAR GIBBSTOWN AT THE POWDER WORKS OF THE REPAUNO CHEMICAL CO.

Seven wells drilled and reported by Andrew Flemstrom.

Elevation, 5 feet ±; diameter of each well, 3 inches; average depth, 78 feet. Water rises to tide level and varies in height with the rise and fall of the tide. Overflows at the surface with high tides.

Two wells drilled and reported by Haines Bros.

No. 1.—Elevation, 5 feet ± ; diameter, 3 inches; drilled to 114 feet and finished at 96 feet.

No. 2.—Elevation, 5 feet ± ; diameter, 6 inches; depth, 90 feet.

Water rises in both wells within about 8 feet of the surface.

The group of seven wells above noted are located on land adjacent to the margin of the marsh between Gibbstown and the Delaware river.

Andrew Flemstrom, who has recently furnished us with the above data, further states that three of these wells were put down in 1899, while the other four were sunk the present year. The group sunk in 1899 are about 1,500 feet west of the group sunk this year. He states that on testing, the three wells of 1899 yielded 300 gallons a minute, while the four of this year yielded 460 gallons a minute. The top of the water-bearing sand was found at the average depth of 75 feet, and the wells were prospected three

feet deeper and finished with strainers at the base 6 feet in length. Yellow clay was encountered at the depth of 45 feet, and lignite and "iron," probably pyrite, at about 60 feet. The water is supplied from within the Raritan beds.

Respecting the group of two wells, Haines Bros. state that they were drilled late in 1902, and that the materials penetrated were sands with a few thin interbedded yellow clay seams to the depth of 80 feet—then coarse gravel to the depth of 96 feet, where decomposed micaceous gneiss rock was encountered, which, at the depth of 114 feet, became hard, solid rock.

The wells are at Thompson's Point, on the Delaware river, a mile north of Gibbstown.

ARTESIAN WELL AT CLARKSBORO.

Elevation, 70 feet; diameter, 3 inches; depth, 178 feet. Water rises within 40 feet of the surface.

Well drilled and data furnished by Haines Bros.

This well was drilled for Charles Stewart.

Soil	15 feet	=	15 feet.
Gravel, with water	5 "	=	20 "
Black, loose clayey sand	40 "	=	60 "
Brownish sand, with water	20 "	=	80 "
Marly clays	85 "	=	165 "
White sand, with water	13 "	=	178 "

This well has a strainer at the bottom four feet long. The white sand carrying water is at the top of the Raritan group.

TWO ARTESIAN WELLS AT SWEDESBORO.

Elevation, 10 feet ±; diameter of each, 6 inches; depth of each, 133 feet. Water overflows at the surface about 15 gallons a minute.

Woolwich Water Co. Drilled and data furnished by Haines Bros.

These wells are additional to one put down last year at the same water works plant and to the same depth, and reported in last year's Annual Report, page 78. They pass from the base of the Clay Marls into the Raritan formation and obtain their supply from the water-horizon at the top of the Raritan formation.

The location is upon the east bank of Raccoon creek. The record, with a slight revision, is the same as that published last year. As revised, it is as follows:

Made ground, meadow muck and running sand in succession	0 feet to 10 feet.			Cretaceous.
Black clay marl	10 " " 70 "	Clay Marl.		
Fine black sand	70 " " 85 "	" "		
Dry black clay	85 " " 110 "	" "		
Coarse sand with water	110 " " 133 "	Raritan.		

The water-horizon is also the same as that supplying a well at Mullica Hill $4\frac{1}{2}$ miles eastward, which well has a depth of 265 feet, the elevation of the surface at the two wells being about the same.

TWO SHALLOW WELLS AT PENNSGROVE.

Elevation, 5 feet ±; diameter of each, 3 inches; depth of each, 30 feet. Water rises within 6 feet of the surface.

In the Annual Report for 1901, page 92, there is noted an unsuccessful boring at this locality to the depth of 334 feet, the lower 50 feet being in the micaceous gneiss rock, which is characteristic of Southeastern Pennsylvania, and outcrops in the hills to the westward across the Delaware river. At that time some water, not then noted in our report, was found in a "coarse gravel with large pebbles and bowlders" between the depths of 22 and 30 feet. The two more shallow wells now noted were sunk to this water-horizon, which is practically a surface one. A lead-colored clay was noted in these shallow borings at their base.

FOUR ARTESIAN WELLS AT HAMMONTON.

Elevation, 120 feet.

Well No. 1—Diameter, 8 inches; depth, 182 feet; length of strainer at the bottom, 20 feet.

Well No. 2—Diameter, 8 inches; depth, 290 feet; length of strainer at the bottom, 40 feet.

Well No. 3—Diameter, 6 inches; depth, 305 feet; length of strainer at the bottom, 60 feet.

Well No. 4—Diameter, 6 inches; depth, 316 feet; length of strainer at the bottom, 60 feet.

Water from Well No. 1 rises within 26 feet of the surface.

Water from Wells Nos. 2, 3 and 4 rises within 30 feet of the surface.

These wells are located adjacent to the Reading Railroad Company's station, and were sunk to supply the town with water. They were drilled by Kisner & Bennett, who kindly furnished full series of the borings and verbally supplied much information. From an examination of these borings, in the light of the information thus supplied, we present the subjoined record. We are also indebted to the borough authorities and to T. Chalkley Hatton, C.E., for courtesies in this connection:

RECORD.

Yellow gravel with iron-stone conglomerate crusts near the top	Surface to	6 feet.		Mainly Sand, 146 feet.
Stiff yellow clay	6 feet "	16 "		
Yellow sand, varying from fine to very coarse (water-bearing, from 25 to 120 feet)	16 "	" 120 "		
Darker yellow clayey sand	120 "	" 146 "		
Stiff black, somewhat sandy clay	146 "	" 156 "		Clays, 16 feet.
Black, very sandy clay	156 "	" 162 "		
Orange yellow sand, with water, supplies Well No. 1	162 "	" 182 "		Sand, 20 feet.
Stiff black clay	182 "	" 196 "		Clays, 48 feet.
Dark, very sandy clay	196 "	" 230 "		
Brownish sand	230 "	" 238 "		Sand, 85 feet.
Sand, very peculiar red (in Well No. 4 only)	238 "	" 244 "		
Coarse, somewhat yellowish sand	244 "	" 315 "		
Water-bearing from 230 to 310 feet, supplies Wells Nos. 2, 3 and 4				
Tenacious, black clay	315 "	" 316 "		Clay, 1 foot, +

After comparing this record with that of a well at Winslow as furnished by Hon. A. K. Hay and recorded by Professor G. H. Cook in Kitchell's* Second Annual Report of the Geological Survey of the State, 1855, page 60, we find a similarity in the succession of the beds down to the depth of 205 feet at Winslow and 230 feet at Hammonton, the elevation of the surface at both localities being the same, or about 120 feet above tide.

* Prof. Cook published a later report of this well in the Geology of New Jersey 1868, in which he described 107 feet of micaceous sand between 150 feet and 257 feet. This interval in his 1855 record was given a threefold subdivision as follows: "Quicksand, 28 feet; black sand, 27 feet; brown sand, 44 feet." It is this earlier record that agrees with this Hammonton section.

In each well at these respective depths the top of a brown sand was entered; this brown sand is stated to be 44 feet thick at Winslow, where, if we may rely upon the record, it rests at the depth of about 248 feet upon a dark-colored or black clay. At Hammonton this brown sand changes to a somewhat yellowish sand towards the base, the two together being 85 feet thick. At the depth of 315 feet these likewise rest upon a black clay, which belongs probably to the same bed as the Winslow clay.

At Hammonton this black clay was not passed through, being penetrated only to the extent of about one foot. At Winslow it was found to be 43 feet thick and to rest at the depth of about 300 feet upon a greensand marl. This depth of 300 feet at Winslow probably indicates the point at which the beds that contain no greensand change to those that do contain it in greater or less quantity. A similar change occurs at Atlantic City, at the depth of 990 feet. A line drawn so as to connect these depths at the two places probably indicates the average dip of the upper part of the greensand beds, *i. e.*, the top probably of the Eocene. The distance between wells at Winslow and Atlantic City is about 31 miles, which, allowing 120 feet for difference in elevation, indicates an average dip along this line of about 26 feet per mile for the base of the Miocene and the top of the Eocene.

The records at Winslow and Hammonton both show that beneath a surface-veneer, not over 15 to 25 feet thick, sands yellowish in color are encountered, and also that the beds are mainly yellow sands, with an exceptional thin black clay-bed to be noted in the next paragraph to about 180 feet. The beds below that depth are none of them yellow.

Two beds of black clay higher than the one already noted as occurring at 248 feet at Winslow and at 315 feet at Hammonton, were found at Hammonton. The higher of these two occupies the interval between 146 and 162 feet, and is a short distance above the base of the yellowish beds of the upper part of the well section, while the lower one occurs between 182 and 230 feet, and marks the division between these upper or yellow beds, and those below that are not yellow.

A similar succession of beds with similar characters has been demonstrated by the wells put down the present year at Millville, as can be seen by comparing this record with the one at Millville, which appears on page 80. At Millville a black clay at 76 to 82

feet, occurs in the yellow beds near their base, while another black clay, the top of which occurs at 92 feet, separates the upper beds which are prevailingly yellowish, from the beds below, which are not at all of that color.

While we do not consider the data so far collected by the Survey as entirely conclusive, we are, nevertheless, inclined to regard the 85 feet of water-bearing sands between 230 and 315 feet, either in their entirety or in part, as probably the equivalent of the great Atlantic City water-horizon that has there a similar thickness and occurs between the depths of 780 and 860 feet. This we have heretofore called the 800-foot Atlantic City water-horizon, from the fact that most of the wells there are prospected to that depth and occasionally somewhat lower.

It will be seen by the record that there are at Hammonton three water-bearing sand and gravel-beds, separated by two clay-beds, while the lowest of the three sand-beds rests upon still another clay-bed. The driller, George B. Kisner, at our request, continued the drilling of the fourth well about one foot into this lowest bed and obtained for the Survey a specimen thereof. From the handling of the drill in the process of the boring he says "the clay in this lowest bed differs from that on the two higher ones in that it is sticky and tenacious, while the two clays above were stiff and sandy." We are inclined to think this lowest bed represents the non-glauconitic Miocene clay, beneath which, elsewhere in the State, there is a sand-bed, sometimes clayey, and always containing more or less true greensand. Careful microscopic examination of all three of these clays fails to reveal any micro-organisms, such as diatoms or foraminifera.

The great 300-foot diatomaceous clay-bed of the Atlantic Coastal plain, which at Atlantic City occupies the interval between the depths of about 400 and 700 feet, is wanting in these borings, although the lower 120 feet of it was met with in well-borings at Egg Harbor, ten miles eastward. The base of this diatom bed probably rises toward tide-level and feathers out midway between these two places, say near DaCosta, and is there overlain by the yellow sands, and perhaps also by the accompanying black clays revealed in the Hammonton borings.

ARTESIAN WELL AT CLAYVILLE, BETWEEN SOUTH VINELAND AND MILLVILLE.

Elevation, about 80 feet; diameter, 1½ inches; depth, 97 feet.

This well was drilled in 1893 by Leach Bros., who then informed us that the materials penetrated were yellowish sands and quicksands all the way down, excepting about 3 feet of dark clay at the depth of about 80 feet. The same firm also put down a second well at the same place, of the exact depth of which we have not been informed, though it was probably finished at about the same depth.

TWENTY ARTESIAN WELLS AT MILLVILLE FOR THE MILLVILLE WATER COMPANY.

Wells.	Diameter.	Depth.	
No. A,	... inches,	685 feet	Test boring.
" C,	4½ "	204 "	Water overflows
" B,	4½ "	76 "	" "
" D,	4½ "	87 "	" "
" 1,	4½ "	172 "	" "
" 2,	4½ "	178 "	" "
" 3,	4½ "	99 "	" "
" 4,	4½ "	126 "	" "
" 5,	4½ "	128 "	" "
" 6,	4½ "	95 "	" "
" 7,	8 "	174 "	" "
" 8,	8 "	101 "	" "
" 9,	4½ "	103 "	" "
" 10,	10 "	69 "	" "
" 11,	8 "	80 "	" "
" 12,	4½ "	66 "	" "
" 13,	6 "	107 "	" "
" 14,	4½ "	101 "	" "
" 15,	4½ "	191 "	" "
" 16,	12 "	74 "	" "

Elevation, about 3 feet above high tide.

Water-horizon at 56 feet to 76 feet.	Upper group.
" " 87 " " 135 "	

Water from this group rises from 10 to 14 feet above tide.

Water-horizon at 150 feet to 191 feet.	Lower group.
" " 204 " " 212 "	

Water from this group rises 22 feet above tide.

The Millville Water Company have for many years supplied that town from the mill-pond there. This water becomes at times slightly colored, and is then what is commonly known as cedar-water. In order to ascertain if a perfectly clear and colorless liquid could be had at all times the company, in 1901, put down a test-boring to the depth of 685 feet. This demonstrated the existence of two satisfactory groups of water-horizons above the depth of about 212 feet, but showed no water-supply of satisfactory quality below that depth. They, therefore, sunk the same year three other more shallow wells, two to the upper and one to the lower of these, and the present year they have put down sixteen others, some to the upper and some to the lower water-horizons. The entire series of wells are arranged along the two arms of an L and are 100 feet apart. The deep well (685 feet) and two of the more shallow wells were noted in last year's report, but for completeness of the record at this time we include these (with one other drilled last year) with the wells drilled this year in the above tabulated exhibit. The wells are located on the flats of the Maurice river, just below the breast of the dam and at the head of tide-water, these flats being about three feet above high tide.

We have designated the wells as they have been designated by the water company. Those of last year are lettered, while those of this year are numbered, the numbers being in the regular order of their occurrence along the two arms of the L and not in the order of time in which they were put down.

The 685-feet boring was not used for water-supply. Fourteen of the wells range in depth from 66 to 128 feet, while the remaining five are between 172 and 204 feet deep.

Through the courtesy of the company and of its engineer we have been furnished with a complete series of the borings from one of the deeper wells of the present year, and as this series is more representative than a similar series received last year, we now present a somewhat revised record, which includes, however, information obtained last year as well as this. Below the depth of 185 feet the record is reproduced with some slight amendment from last year.

Yellow sand from near the surface to the depth of				56	feet.	
Yellow sand and coarse gravel with a good supply of water	56	feet	to	76	"	
Black clay	76	"	"	82	"	
Yellow clay	82	"	"	85	"	
Yellow gravel	85	"	"	92	"	
Black clay	92	"	"	98	"	Probably in part, if not wholly, Miocene.
Alternations of dark clay seams with sands containing water	98	"	"	135	"	
Black clay with casts of marine bivalves	135	"	"	150	"	
Coarse brownish gray *water-bearing* sands	150	"	"	185	"	
Clay and coarse gravel, some diatoms and also iron pyrite	185	"	"	204	"	Miocene.
Gravel with "a good flow of *water*"	204	"	"	212	"	
Dark brown clay, no diatoms, but first appearance of fossil mollusks in which the shell itself is preserved	212	"	"	221	"	
Gravel, with some shells	221	"	"	233	"	
Dark clay, no diatoms	233	"	"	241	"	
Clay, gravel and some shells	241	"	"	255	"	
Clay, sandy at the top	255	"	"	300	"	
Clay, with comminuted shells	300	"	"	310	"	
Dark brown clay	310	"	"	360	"	
Greenish clay	360	"	"	370	"	
Brownish sandy clay	370	"	"	375	"	
					(?)	
Greenish mixture of quartz and green sand	375	"	"	395	"	Upper Layer Upper Marl Bed.
Dark olive-green sandy marl, with abundance of greensand grains	395	"	"	438	"	
Similar dark olive-green sandy marl, but somewhat more clayey	438	"	"	526	"	
Greenish mixture of quartz and greensand, with some fossil shells	526	"	"	552	"	
					(?)	
Greenish sandy clay, with some green sand and some fossil shells	552	"	"	630	"	Lower Layers Upper Marl Bed.
Similar greenish sandy clay, but with much more green sand	630	"	"	675	"	
Dark olive-green clayey marl	675	"	"	680	"	
Hard rock, slightly calcareous	680	"	"	685	"	Probably Limesand

In one of the wells put down this year, at the depth of 135 feet, at the top of the black clay in which occurred casts of marine shells, we found one small flat laminated and indurated pebble about the size and thickness of a dime, which, on being split, unmistakably showed on the inner faces the microscopic remains of marine diatoms. No other diatoms, however, were discovered by a microscopic examination of the clays until the depth of 200 feet was reached.

As already noted, these wells demonstrate the existence at this locality of two groups of water-horizons. The upper of these was developed by the wells whose depths range between 66 and 128 feet. This horizon has also been developed by other wells put down at Millville, at both the upper and the lower glass manufactories of Whitall, Tatum & Co., and also at the plant of the People's Water Company. All of these wells are on the meadows adjacent to the Maurice river, and all of them lower down along the course of that stream. We also regard this horizon as the equivalent of that supplying six wells put down at Vineland for the public water-supply there, which range in depth between 125 and 150 feet, the elevation of the surface being 80 feet. It is also probably the same as that which supplies wells at Bridgeton, whose depths vary from about 80 to 115 feet, according to the elevation. We would further tentatively suggest that it may be the same horizon as has been developed at Hammonton between the depths of 162 feet and 182 feet, and which supplies Well No. 1 at that place (page 74). The lower group of horizons at Millville supplies the wells whose depths range from 172 to 204 feet. We tentatively suggest that this may be the equivalent of the horizon developed by three wells at Hammonton, whose depths range from 290 to 315 feet, the horizon seeming to have a maximum thickness of about 60 to 65 feet. The elevation at Hammonton is about 120 feet above tide.

We are not yet able to correlate with certainty this horizon with any of the water-horizons at Atlantic City, but we suspect that these lower water-bearing sands at Hammonton and at Millville are the same as the great 800-foot Atlantic City water-horizon.

TWO ARTESIAN WELLS AT BIVALVE.

No. 1 sunk for John Yates. Diameter, 2 inches; depth, 198 feet.
No. 2 sunk for Campbell & Bateman. Diameter, 2 inches; depth, 201 feet.
Elevation of each well about 1 foot above ordinary high tide.
Water at 120 to 150 feet that rises 2½ feet above the surface.
Water at 187 to 201 feet that rises from 10 to 11 feet above the surface, varying in height with the tides.

Both wells drilled and reported by George D. Fagan & Son.

These wells were put down in the year 1897 at the oyster-shipping village of Bivalve, which is situated on the marshy flats

near the mouth of Maurice river and about one mile due south of Port Norris. George D. Fagan & Son have kindly furnished the following record. Except for unimportant differences in the first two members, it will be noticed that the beds penetrated are the same and of the same thickness in each:

	John Yates' No 1 well.	Campbell & Bateman, No. 2 well.	Total depths.
Marsh mud	20 feet.	40 feet.	
Beach sand	30 "	10 "	50 feet.
Black quicksand	20 "	20 "	70 "
"Dark mud" or clay	20 "	20 "	90 "
Quicksand	30 "	30 "	120 "
Alternations of clays and sands, water-bearing	30 "	30 "	150 "
Dark stiff hard dry clay	15 "	15 "	165 "
Light-colored quicksand	13 "	13 "	178 "
Rock, described as "porous and like coral"	9 "	9 "	187 "
Coarse white sand, water-bearing	11 "	11 "	198 "
Same continued in Well No. 2		3 "	201 "

The greater depth of marsh deposit in Well No. 2 (40 feet) than in Well No. 1 (20 feet) was because Well No. 2 was nearer the channel of Maurice river than Well No. 1. The depth of 40 feet for these deposits agrees with the maximum depth of the marsh beneath League Island, at the mouth of the Schuylkill (36 feet), and also with the maximum depth of the marsh (40 feet) at the mouth of the Pensauken.

In drilling these wells, water, which, however, was not utilized, was found between the depths of 120 and 150 feet. This water rose about 2½ feet above the surface. This is doubtless the same horizon as that which supplies the well in the town of Port Norris (page 83).

The water from the lower horizon, between the depth of 187 to 201 feet, rises and falls with the tides in the adjacent river. At a height above the surface of 10 or 11 feet the amount of variation is 15 inches.

It is probable also that the water from the higher horizon (viz., 120 to 150 feet), would also have shown a similar tidal variation had a test been made. It will be observed, however, the water from this horizon did not head as high above the surface as does that from the lower one.

ARTESIAN WELL TWO AND ONE-HALF MILES SOUTH OF DIVIDING CREEK.

Sunk for Stultz & Berry.
Elevation, level of tide marsh; diameter, 2 inches; depth, 198 feet.
Water overflows at the surface and rises about 10 feet above it. The quantity overflowing varies from a bucketful, in 17 seconds at high tide, to one in 27 seconds at low tide.

Well drilled and data furnished by George D. Fagan & Son.

This well was put down in 1899. It is located midway in the broad salt marshes that stretch between the town of Dividing Creek and Maurice river cove, Delaware bay. George D. Fagan states that the beds penetrated were the same in succession and in thickness as were found in John Yates' well (No. 1) at Bivalve, four miles to the east. (See preceding record.)

ARTESIAN WELL AT PORT NORRIS.

Sunk for L. M. Lee.
Elevation, 5 feet; diameter, 2 inches; depth, 126 feet.
Water rises 2½ feet above the surface.

Drilled and reported by George D. Fagan & Son.

This well was put down in 1901 and is located on the main street of Port Norris, near the head of a small stream that empties into Maurice river at Bivalve. The water supplying this well is the same as that found below the depth of 120 feet in the two wells at Bivalve (page 81), where, however, it was not utilized. The record furnished by George D. Fagan & Son is as follows:

		Total depths.
Marsh mud	6 feet	= 6 feet.
Yellow gravel	9 "	= 15 "
Lead-colored quicksand	20 "	= 35 "
Coarse dark sand	65 "	= 100 "
Alternating layers of clay and sand	15 "	= 115 "
Dark quicksand	8 "	= 123 "
Same quicksand continued, with water that overflowed	3 "	= 126 "

ARTESIAN WELL AT WOODBINE.

Elevation, 40 feet; diameter, 6 inches; depth, 120 feet.
Water rises within 13 feet of the surface.

Drilled and reported by Thomas B. Harper.

This locality is at the head of the Cape May peninsula, and is midway between Great Egg Harbor bay and Maurice river cove.

The well was put down for the Woodbine Machine and Tool Company, at their factory near the railroad station.

From a series of the borings furnished the Survey we are able to present the record below:

Surface beds	0	feet	to	9	feet.
Sand and gravel with fossiliferous (Silurian) pebbles	9	"	"	11	"
Yellow sand	11	"	"	33	"
Orange-colored coarse sand	33	"	"	40	"
Fine sandy clay, yellow	40	"	"	50	"
Coarse clayey sand (deeper yellow)	50	"	"	60	"
Medium yellow sand	60	"	"	70	"
Coarse, sandy clay	70	"	"	90	"
Finer sandy clay	90	"	"	100	"
Darker clayey sand	100	"	"	110	"
Coarse yellow sand water-bearing	110	"	"	120	"

It will be noticed that the beds are prevailingly yellow all the way to the base of the well. Microscopic examination of the clays fails to reveal any micro-organisms.

ARTESIAN WELLS AT CAPE MAY.

Elevation of surface, 10 feet ±.

	Diameters.					
One test well,	10	inches to	85	feet.	Total depth, 1,313 feet.
	8	" "	420	"	
	6	" "	677	"	
	4½	" "	812	"	
	2½	" "	1,120	"	
	Prospected with the drill to		1,313	"	

This well was afterward finished to draw water from below the depth of 587 feet .... } Wildwood Water-Horizon.
Water rises within about 4 feet of the surface.

Six more shallow wells.

No. 1	diameter,	8	inches	depth,	124	feet.	Cape May Water-Horizon.
No. 2	"	8	"	"	125	"	
No. 3	"	8	"	"	122	"	
No. 4	"	8	"	"	125	"	
No. 5	"	8	"	"	121	"	
No. 6	"	8	"	"	120	"	

Water stands at about 14 feet from the surface, with the pumps working.

Early the present year the city authorities of Cape May determined to seek a supply of water by means of deep-well borings, very properly expecting to find at about 900 feet the same water-horizon as occurs at Atlantic City between 780 and 860 feet. This was the more to be expected since its existence beneath the beaches from Harvey Cedars southward to Wildwood had previously been demonstrated.

Accordingly, a contract was made with Thomas B. Harper, who had already successfully put down wells to this horizon at Atlantic City and Ocean City. Contrary to expectation, however, water was not found at 900 feet, although beds somewhat similar to the Atlantic City horizon, both in texture, color and thickness, were found at about the proper stratigraphical position. The first well was therefore continued as a test-boring to the depth of 1,313 feet, but without finding an available supply of water at these depths.

Water-yielding strata were, however, observed between the depths of 90 and 130 feet, of 285 and 300 feet, and of 585 and 600 feet. Consequently this well was finally finished at the depth of 587 feet, so as to draw from the lowest of these three water-horizons, and six other wells were sunk to depths between 120 and 125 feet, to the upper of the three horizons. These more shallow wells are provided with strainers at the base 30 feet long. No well was sunk to, nor test made of the second of these horizons, viz., that at 285 to 300 feet.

Full series of the borings, carefully taken at every ten feet, have been courteously furnished the Survey through the co-operation of Thomas B. Harper, T. Chalkley Hatton, C.E., and of the engineer at the pumping-station, James Rice. We are also indebted to members of the City Council and to Franklin B.

Speace, of the Fire Department, for aid in our investigations and to all of the parties referred to for verbal information from time to time during the progress of the drilling.

From our study of the specimens and of the data thus obtained we are enabled to present the subjoined stratigraphical record:

CAPE MAY.

Sands and gravels of various shades of yellow, gray, buff and orange...........	surface to	52 feet		Recent.
Black clay, with *recent marine diatoms* and sponge spicules containing also marine mollusks, viz., *Gemma manhattenensis* Prime and *Pholas costata*, Linn..........	52 feet "	62 "	Diatoms Triceratium favus, &c., and Northern Mollusks.	
Greenish very sandy clay, containing (probably at the base) the following mollusks, viz., *Rangia cuneata*, Gray, and *Pholas costata*, Linn..........	62 " "	85 "	Southern Mollusks.	Age?
Sponge spicules at 72 and 82 feet.				
Heavy whitish gravels, with large pebbles and cobbles, one of the latter showing well marked *Scolithus linearis*, a Cambrian fossil..........	85 " "	90 "		
Mixture of coarse gray sand and fine gravel, *water bearing*, supplying the six more shallow wells..........	90 " "	140 "	Cape May Water-Horizon.	
White, very fine clayey sand..........	140 " "	160 "		
Dark gray sand very clayey at the base, no micro-organisms in the clay,	160 " "	180 "		
White sand and gravel mixed	180 " "	190 "		
Darker gray, very clayey sand, containing no micro-organisms..........	190 " "	212 "		
A few fragments of much comminuted mollusks, apparently bivalves at......		212 "		
Lighter colored sand, still quite clayey and without micro organisms..........	212 " "	240 "		
Darker, slightly brownish-gray sands, ranging from fine to coarse, and sometimes quite clayey, no micro-organisms..........	240 " "	270 "		
Lignite plentiful at..........		270 "		
Lighter colored gray sand..........	270 " "	285 "		
Coarser gray sand, water bearing, but not utilized for water supply	285 " "	300 "	Holly Beach Water-Horizon.	
Brownish yellow sand..........	300 " "	310 "		

Stratum	Depth	Horizon	Bed	Series
Dark clays and sandy clays, without diatoms or other micro-organisms	310 feet to 340 feet.			Miocene.
Comminuted shells at	340 "			
Dark very clayey sands	340 " " 360 "		The Great Diatom Bed, 310 feet thick.	
Coarse sand and fine gravel	360 " " 367 "			
Dark mixture of sand, gravel and clay containing throughout *sponge spicules* and *Miocene marine diatoms*, Miocene mollusks at 370 to 385 feet, at 400 feet and at 420 to 440 feet.	367 " " 440 "	Upper Part of the Great Diatom Clay Bed.		
Sand	440 " " 450 "			
Dark colored, fine, very clayey sand with *sponge spicules* and *diatoms* throughout	450 " " 522 "			
Comminuted shell at 510 to 520 feet.				
Rock seam 1 feet thick, probably indurated sand	522 " " 538 "			
Fine and coarse gray gravels with black barnacles and white molluscan shells	538 " " 560 "			
Some shell at 550 feet.				
Lignite at	560 "			
Grayish coarse sands and fine gravels. Water bearing, supplies the deep well as finally finished. This bed includes a rock seam one foot thick between 584 feet and 585 feet. Lignite occurred at 590 feet	560 " " 600 "	Wildwood Water-Horizon.		
Brown sandy micaceous clay with sponge spicules and abundance of diatoms, among the latter notably *Actinocyclus ehrenbergii*, Ralfs	600 " " 660 "	Lower Part of the Great Diatom Bed. Actinocyclus, &c.		
Gray sand	660 " " 677 "			
Rock stratum 17 feet thick, probably indurated sand	677 " " 694 "	Non-diatomaceous, — Atlantic City, 690–780 feet.		
Gray sand	694 " " 712 "			
Some comminuted shells at 700 feet.				
Rock seam feet thick	712 " " 717 "			
Very fine dark gray sand somewhat clayey	717 " " 775 "			
Still darker (somewhat greenish) and slightly coarser gray sand, with mollusks at 78 to 79 feet.	775 " " 790 "	Supposed Equivalent of Atlantic City 800-foot Water-Horizon.		
Mixture of coarse gray sand and fine and coarse gravel, with plenty of molluscan fossils	790 " " 812 "			
Rock seam 6 feet thick	812 " " 818 "			
Coarse gray sand and gravel	818 " " 825 "			
Brownish mixture of clay sand and gravel with comminuted shells, but no micro-organisms	825 " " 849 "			
Rock seam one foot thick.	849 " " 850 "			
Very fine clayey sand.	850 " " 880 "			
Fine sandy brownish clay containing throughout an abundance of sponge spicules and a considerable number of diatoms notably among the latter, great numbers of *Actinoptychus heliopelta* Grunow	880 " " 980 "	Lesser Diatom Bed. Actinoptychus heliopelta, &c.	Diatom Bed, 110 feet thick.	
Mixture of diatom clay, sand, gravel and molluscan shells	980 " " 990 "			

The beds above this depth (990 feet) contain no glauconite or greensand, but below this depth all the beds penetrated contain more or less greensand.				
Dark gray sand somewhat micaceous, contains considerable greensand	990 feet to 1,020 feet	Moderately Glauconitic Beds.	Very Dark Green in Color.	Probably in part if not wholly, Eocene.
Dark greenish sand, with a large proportion of greensand, with some comminuted small shells at the base,	1,020 " " 1,040 "			
Dark gray sand similar to that at 990 to 1,020 feet, but with more clay in the matrix, also somewhat micaceous	1,040 " " 1,070 "			
Dark greensand similar to that at 1,020 to 1,040 feet, but with less comminuted shell	1,070 " " 1,080 "			
Greenish-gray, coarse sand and fine gravel mixed, consisting mostly of white quartz grains, with a small admixture of greensand	1,080 " " 1,090 "	Somewhat Quartzose and slightly Glauconitic Sands.		
Fragments of an echinus at	1,090 "			
Similar greenish-gray sand, but without gravel	1,090 " " 1,110 "			
Somewhat clayey sand, brownish-gray in color, the grains mostly quartzose, containing, however, a few greensand grains. "A very little water just trickled over the top of the well at 1,120 feet"	1,110 " " 1,130 "			
Clayey sand, consisting largely of greensand	1,130 " " 1,140 "			
Black or dark green greensand, somewhat clayey, very little gray sand in this	1,140 " " 1,160 "			
Olive green, nearly pure greensand, somewhat clayey	1,160 " " 1,280 "	Highly Glauconitic Beds.	Rusty Green	
Some mollusks at	1,280 "			
Olive green greensand, still more clayey	1,280 " " 1,313 "			
Some *foraminifera* at 1,300 feet				

A notable feature in the above section is the occurrence of six indurated seams, or rock-beds, two of which are respectively 11 and 17 feet thick. At Atlantic City one such bed, and one only, about one foot thick, usually occurs at the depth of 690 feet. The well records show that these rock-seams increase in number and in thickness southward, until the maximum, both in number and in thickness, has been obtained at Cape May. The two diatomaceous clay-beds in the Miocene are also interesting features.

Correlations.

The following water-horizons are known to exist at Cape May:

Surface wells.—These are dug to depths of 5 to 12 feet.

Driven wells.—These extend to depths of 25 to 30 feet. (Annual Report for 1900, p. 126.)

The Cape May water-horizon.—This horizon occupies the interval between the depths of 87 and 125 feet, and supplies the six shallow wells put down the present year to depths varying from 120 to 125 feet, and also nineteen other wells put down a few years since to depths varying from 79 to 106 feet. (Annual Report for 1900, p. 126.)

The Holly Beach water-horizon.—This occurs between the depths of 285 and 300 feet. It was noticed in drilling the deep well but was not utilized. We predicted this horizon at Cape May in the Annual Report for 1900, page 122, though at a slightly greater depth. It is known also at the following places:

	Interval of depth.	
At Sea Isle City	261 to 278 feet,	not utilized.
At Avalon	270 " 280 "	" "
At Anglesea	284 " 331 "	supplies one well.
At Holly Beach	310 " 326 "	" " "

The Wildwood water-horizon.—This occurs at Cape May, between the depths of 585 and 600 feet and supplies the one deep well at the water-works. It is believed to be the equivalent of that at Bivalve at the depth of 200 feet, at Atlantic City at 525 to 550 feet, and at Wildwood at 620 to 648 feet. It occurs midway in the great 300-foot diatom bed.

All the above horizons are stratigraphically higher than the great 800-foot Atlantic City water-horizon, which seems to be wanting at Cape May, although non-water bearing beds, probably its equivalent stratigraphically, occur between the depths of 775 and 860 feet.

At 1,120 feet.—This scanty water-bearing horizon probably corresponds with that at Wildwood at 1,185 feet.* It may also be the equivalent of that at Atlantic City at 1,135 feet, in the

*Annual Report for 1894, p 178. On page 159 of that report it is wrongly printed as at 1,085 feet.

gas-works well, put down in 1888-89, and still flowing. The supply of water is abundant and the quality satisfactory at Atlantic City. At Wildwood the flow was copious, but the water was salty. Further northward, along the beaches, as well as in the interior of Southern New Jersey, this horizon, if found, may perhaps yield, at least in some localities, water satisfactory both as to quality and quantity.*

Fossils.

At 52 to 62 feet: a cold water form.—The black clay at this horizon contains recent diatoms—one characteristic form, *Triceratium favus,* Ehren, being found in the muds now being deposited along the bays and rivers of the coast. It has also been found in the mud of the Delaware river as far up as Philadelphia. Associated with the black clay are also fragments of *Pholas costata,* Linne, and perfect shells of *Gemma Manhattensis,* Prime, both recent forms, and the latter a minute clam typical of the colder waters of the New England coast, but now not known south of Long Island.

At 85 to 90 feet: a warm water form.—Beneath the black clay—perhaps as much as thirty feet—numerous specimens of a larger clam, *Rangia cuneata,* Gray, were found along with fragments of *Pholas costata.* The former is now abundant in the warmer waters of the Gulf States, and occurs very sparingly on the Atlantic coast, but not, so far as known, north of Cape Hatteras.

At 310 to 360 feet: Miocene Fossils.—Finely comminuted but unrecognizable shells were obtained from this horizon, but from a well at Cape May Point (Annual Report for 1894, p. 158) at the same horizon, Miocene fossils have been found (see above report for list). Microscopic examination failed to reveal any micro-organisms such as diatoms or foraminifera.

Miocene diatom beds at 367 to 677 feet.—This is the great Miocene diatom bed of the coastal plain, frequently referred to in these reports and described fully in the Annual Report for 1894, pp. 165-169. At 625 feet at Atlantic City and at 600-640 feet at Cape May, numerous specimens of the diatom *Actinocyclus ehrenbergii,* Ralfs, have been found.

* For a resumé of well data at Cape May and vicinity previous to the present time, those especially interested are referred to the Annual Report for 1900, pp. 120-131.

Comminuted fragments of Miocene molluscan shells also occurred at various depths within this diatom clay-bed. The fossils were usually ground to pieces in the process of drilling, but occasionally unbroken forms were obtained.

At 395 feet.—Good specimens of *Astarte arata,* Conrad, were obtained from this depth.

At 480 to 500 feet.—Considerable numbers of whole shells, together with larger fragments, were obtained from a depth reported as 480 to 500 feet.* Of these Mr. C. W. Johnson has identified the following:

Pecten madisonius, Say.
Nucula proxima, Say.
Corbula inæquale, Say.
Mytilus incrassatus, Conr.
†*Venus mercenaria,* Linn (young).
Ecphora quadricostata, Say.
Crucibulm constrictum, Conr.
Polinices perspectiva, Rogers (young)
Polinices duplicata, Say.
Calyptræa perarmata, Conr.
†*Melanopsis,* —— sp. ?
Serpulorbis gramifera, Say.
Turritella cumberlandia, Conr.
Turritella æquistriata, Conr.
Turritella plebeia, Say.
Cancellaria biplicifera, Conr.
Cancellaria, —— sp. ?
Nassa bidentata, Emmons.
Nassa peralta, Conr.
Crepidula convexa, Say.
Oliva, —— sp. ?
†*Terebra inornata,* Whitf.
†*Terebra,* —— sp. ?

* For certain reasons connected with the process employed in drilling this well, it may be that some and perhaps many of the shells thus obtained and marked may have come from a somewhat higher horizon, namely, that of 385 to 390 feet; while others may have been distributed between that depth and the lower depth (480 to 500 feet).

† Forms marked † were also found among the fossils at the Cape May Point well, from a higher horizon (320 to 360 feet). An. Rep. 1894, p. 158.

Astyris communis, Conr.
Calliostoma, —— sp. ?
Actæon, —— sp. ?
Semele carinata, Conr. (young).
Cerithiopsis bisulcata, Conr.
Mulinea, —— sp. ?
Urosalpinx cinerea.
Seila adamsii, H. C. Lea.
Balanus proteus, Conr.

At 575 feet.—C. W. Johnson was able to identify the following fossils from this horizon:

Astarte concentrica, Conr.
Polinices perspectiva, Conr.
Neptunea, —— sp. ?
Nucula, —— sp. ?
Venus, —— sp. ?
Meretrix, —— sp. ?
Balanus proteus, Conr.

At Beach Haven and Egg Harbor City this diatom bed rests directly upon the 800-foot Atlantic City water-horizon, while at Smith's Landing, Brigantine, Atlantic City, Ventnor, Longport, Ocean City, Sea Isle City, Avalon and Wildwood there intervene between the diatom bed and the water-yielding sand, non-diatomaceous strata consisting mostly of clay. At Cape May, also, non-diatomaceous clay-beds occur between the great diatom bed, and the non-water yielding sandy strata which are supposed to be the equivalent of the 800-foot Atlantic City water-horizon.

Miocene diatom beds at 880 to 980 feet.—This diatom bed has a thickness of about 100 feet. It is characterized by the occurrence of the diatom *Actinoptychus heliopelta,* Grunow,* which is not found in the great diatom bed above.

This form has been found in clays outcropping at Asbury Park and near Shiloh, N. J., also near Nottingham and Marlboro, Md., and also in borings at Clayton, Del. (100 to 150 feet); Lewes, Del. (910-990 feet); at Crisfield, Md. (790 feet), and at Wildwood, N. J. (1,040 feet). Excepting at Shiloh, these clays rest directly upon beds containing more or less greensand

* This diatom is figured on Plate VI., p. 172, Annual Report for 18?4.

marl, while at Shiloh the interval cannot be great. A clay very similar in color and in composition occurs at Atlantic City (860-990 feet), but here we have not been able, after repeated microscopic examinations of specimens from two deep borings, to find any diatoms. This bed is apparently richly diatomaceous to the southwest and very sparingly or at times not at all diatomaceous to the northeast.

At 990 feet.—Here greensand marl becomes a noticeable constituent, there being no greensand grains in any beds higher up. This change has been noted in wells at other localities, as follows:

At Crisfield, Md.	790	feet.
At Lewes, Del.	990	"
At Wildwood	1,104	"
At Atlantic City	990	"
At Island Heights	285	"
At Asbury Park ....about	80	"

This line is supposed to mark the base of the Miocene and the top of the Eocene.

A shell-bed apparently occurs just above this line at Cape May, but the fragmentary condition of the specimens renders identification difficult. Mr. C. W. Johnson has recognized the following:

Mactra, —— sp. ?
Odostomia, —— sp. ?
Nucula, —— sp. ?
Yoldia lævis, Say,
Turbonilla interrupta, Totten (?)
Cadulus thallus, Conr.
Balanus proteus, Conr.

A foraminifera, genus *Biloculina,* was also observed. A similar shell-bed occurs at Wildwood at the corresponding depth (1,100 feet).

At 990 to 1,313 feet.—These greensand beds have been recognized elsewhere as follows:

At Island Heights	between	285	and	504	feet.	
At Atlantic City	"	990	"	1,240	"	
At Millville	"	370	"	552	"	
At Wildwood	"	1,104	"	1,244	"	+
At Lewes, Del.	"	990	"	1,080	"	+

ARTESIAN WELLS AT OCEAN CITY.

One well at water works pumping station, Tenth street, south of the Reading railroad station.

Elevation, 5 feet; diameter, 6 inches; depth, 816 feet.
Water overflows at the surface about 40 gallons a minute, and yields, by pumping, about 175 gallons a minute.

One well at Hotel Aetna.

Elevation, 10 feet; diameter, 4½ inches; depth, 812 feet.
Water did not overflow but yielded, by pumping, about 150 gallons a minute.

Both wells were drilled and reported by Thomas B. Harper.

Both these wells were finished with strainers at the bottom, each 50 feet in length. In drilling the water works well a hard streak, as of stone or rock one foot thick, was encountered at the depth of 632 feet. The great 300-foot diatom clay-bed was passed between the depth of about 390 and 690 feet. A brown sand was also noted in the same boring midway in this diatom bed or between the depth of 550 to 565 feet. The well at the Aetna was on higher ground than the one at the water works, and hence did not overflow. Both wells are supplied from the 800-foot Atlantic City water-horizon.

ARTESIAN WELL AT SOUTH ATLANTIC CITY.

Elevation, 5 feet ±; diameter, 8 inches; depth, 810 feet.
Water overflows 40 gallons per minute.

Drilled and reported by Thomas B. Harper.

This well is situated on the meadows west of the railroad and about three blocks south of the gigantic figure of the elephant that adorns the beach at this locality. The well was finished at the base with a screen fifty feet in length. The water-horizon reached is that which we have designated as the Atlantic City water-horizon, which occurs in a sand-bed some 50 or 60 feet in thickness, the average depth thereto from Atlantic City to Longport is about 800 feet.

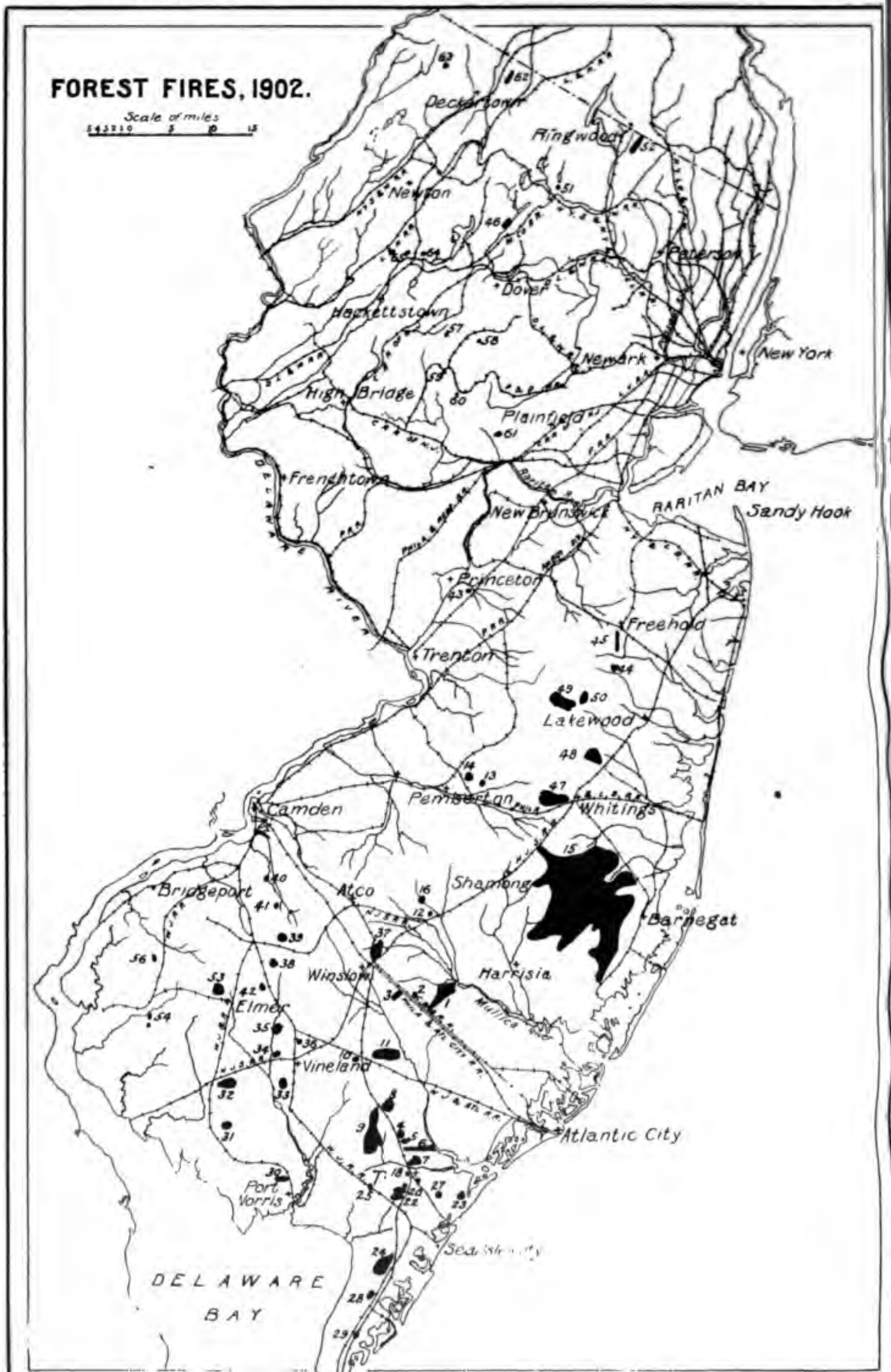
The strata penetrated by this boring agree very closely, depth for depth, with the numerous records that have already been published in past annual reports of wells at Atlantic City, and include, between the depths of about 400 and 700 feet, the great 300-foot Miocene diatom clay-bed.

ARTESIAN WELL AT LEED'S POINT.

Elevation, 55 feet; diameter, 6 inches; depth, 160 feet. Water rises within 40 feet of the surface.

Drilled and reported by Thomas B. Harper.

This well was put down for Robert Scott. From a specimen of sand received from the bottom of this well we judge that the water comes from a brownish sand-bed that overlies the great diatom clay-bed. This brown sand occurs in the Atlantic City wells between the depths of 270 and 390 feet. This well is located about nine miles nearly due north of the wells at Atlantic City, while the wells at both localities are nearly upon longitude line 74° 26′. The one, however, at Leed's Point is about five miles farther back on the dip of the beds than those at Atlantic City.



MAP SHOWING THE EXTENT OF THE FOREST FIRES IN NEW JERSEY DURING 1902.

PART III.

Forest Fires in New Jersey During 1902.

Notes on Basket-Willow Culture.

By F. R. MEIER.

Forest Fires in New Jersey During 1902.

BY F. R. MEIER.

During the past season fires have continued to devastate large areas of timber-land, particularly in Atlantic, Burlington, Cape May and Ocean counties. The northern half of the State, however, has not escaped, as is shown by the record given below of fires in Morris, Passaic, Somerset and Sussex counties.

In order to determine accurately the areas traversed by these fires and the damage done, each burned tract was visited and the character of the timber examined. It is believed that the damage has been conservatively estimated, and that the figures are too low rather than too high. For convenience the list is arranged by counties.

ATLANTIC COUNTY.

1. April 25th, 1902. Fire started in the village of Elwood from a burning house, and burned on both sides of the road from Elwood to Pleasant Mills, over a section four miles long, one and one-half miles wide; comprising 3,500 acres, covered with young timber from ten to thirty years old, some of which was particularly good. The fire was very severe, killing all trees, pitch pine, yellow pine, white, red and black oak, cedar and chestnut, including two chestnut plantations. Several buildings and one church were also destroyed, which are not included in the estimated damages. Fire lasted eight hours; average loss, $2 per acre; total loss, $7,000.

2. June 6th, 1902. A fire occurred along the railroad tracks between Elwood and Hammonton, caused by a locomotive. It covered twenty-seven acres of young pitch pine twenty years old, which was partly burned. Average loss, $4 per acre; total, $108.

3. April, 1902. Southwest of DaCosta, a farmer burning brush, started a fire which swept over eighty acres of pine and oak timber ripe for cordwood, which was partly killed, partly injured. Average loss, $4.50 per acre; total loss, $360.

4, 5, 6, 7. April 25th or 27th, 1902. At the so-called Lee Crossing, south of Ridley station, four fires were set by locomotives. They burned from the railroad to the Great Egg Harbor river. The burned areas comprised (*a*) 200 acres of oak and pine fifteen years old, killed; average loss, $3 per acre; total loss, $600; (*b*) 160 acres oak and pine ten years old, injured; average loss, $2 per acre; total loss, $320; (*c*) 1,200 acres oak and pine, ten to forty years old, killed; average loss, $5 per acre; total loss, $6,000; (*d*) 150 acres oak and pine twenty years old, killed; average loss, $4 per acre; total, $600.

8. May 2d, 1902. Near Millway, a fire caused by a locomotive swept over 150 acres of oak and pine, twenty years old, and of good growth, which was entirely killed. Average loss, $4 per acre; total, $600.

9. April 26th, 1902. One mile west of Millway, a locomotive started a fire which burned 5,000 acres of pitch pine, white oak, black and red oak, and two small cedar swamps of four and five acres, respectively. Eight hundred acres were of fine oak and pine, thirty years old, the rest from ten to fifteen years old. Average loss, $3 per acre; total, $15,000.

10. May, 1902. One mile west of Richland, a fire was caused by Italians clearing land. Fifty acres of fine oak and pine timber, forty years old, were burned, causing an average loss of $6 per acre; total, $300.

11. May, 1902. Between Richland and Weymouth, another fire was also started by Italians clearing land. It injured, but did not kill, 900 acres of pine, ten to thirty years old. Average loss, $1.75 per acre; total, $1,575.

BURLINGTON COUNTY.

12. May, 1902. Near Atsion, eight acres of pine, eighteen years old, were killed by a fire started by a locomotive. Average loss, $5 per acre; total, $40.

13, 14. May, 1902. At Brown's Mills, charcoal-burners set two fires which swept over 100 acres, but owing to repeated burnings of this tract the damage was inconsiderable.

15. May 9th, 1902. Locomotive sparks started a fire near Woodmansie, which burned 75,000 acres, one-third in Burlington, two-thirds in Ocean county. This fire swept in a southeasterly direction to the coast, lasting three days on one wing, and ten days on the other, and burning over a tract twenty miles long and from one to eight miles wide. The little village of Jungs Neck was in great danger of being destroyed. The fire was finally extinguished by rain, after burning some fine pine and cedar timber. No effort was made to extinguish this fire except where it threatened the village of Jungs Neck. Average loss, $1 per acre; total, $75,000.

16. July, 1902. Three miles north of Atsion, smokers started fires which burned twenty acres of pine, eighteen years old. The timber was killed. Average loss, $3 per acre; total, $60.

CAPE MAY COUNTY.

17. May 21st. Two miles south of Tuckahoe, a fire started by a locomotive entirely killed thirty acres of oak and pine of poor quality, thirty years old. Average loss, $2 per acre; total, $60. It also burned fifty-three acres of seasoned cordwood worth $2 per cord, $106.

18. June 5th, 1902. In Tuckahoe, ten cords of oak cordwood, worth $2 per cord, were burned by a fire started by a locomotive.

19. August 20th, 1902. East of Steelmantown, a locomotive set fire to eleven cords of seasoned oak cordwood valued at $2 per cord; total, $22.

20. August 20th, 1902. East of Steelmantown, a locomotive set fire to 500 acres of oak and pine timber of fine quality, fifteen years old. It was partly killed and partly stunted. Average loss, $3 per acre; total, $1,500.

21. August 21st, 1902. Another fire, also east of Steelmantown, due to a locomotive, burned 150 acres of oak and pine of fine quality, fifteen years old. The timber was killed. Average loss, $5 per acre; total, $750.

22. August 21st, 1902. The same day a second fire, east of Steelmantown, also due to a locomotive, burned 250 acres of second-class oak timber, fifteen years old. Timber was injured, but not killed. Average loss, $2 per acre; total, $500.

23. May 16th, 1902. At Palermo, a fire, cause unknown, traversed sixty-five acres of oak and some pine of poor quality, five to twenty years old. Timber was partly killed. Average loss, $0.50 per acre; total, $32.

24. May, 1902. A fire, due to a locomotive, swept from Dennisville to Goshen, burning 800 acres of scattered pine with some good oaks, from ten to twenty-five years old. It was finally extinguished by an organized party of eight men, employed by the owner of the property. Average loss, $1.50 per acre; total, $1,200.

25. August 12th, 1902. At Woodbine, a fire, set by a locomotive, was extinguished by section men and citizens of Woodbine before damage was done.

26. August 19th, 1902. A second fire at Woodbine, a week later, also due to a locomotive, was extinguished by section men and citizens of Woodbine, without damage. These two instances show what can be accomplished by prompt action.

27. August, 1902. At Petersburg, a farmer, in clearing land, caused a fire which burned ninety acres of poor woodland. Owing to repeated burning the tract was of little value. Average loss, $0.50 per acre; total, $45.

28. May, 1902. Near Anglesea Junction, an incendiary fire destroyed forty-five acres of fine pine and oak, of forty years' growth. Average loss, $10 per acre; total, $450.

29. April, 1902. Near Rio Grande, fire set by smokers burned and killed twenty acres of pine sprouts, twelve years old. Average loss, $1 per acre; total, $20.

CUMBERLAND COUNTY.

30. May, 1902. About two and one-half miles east of Dividing Creek, locomotive sparks set fire to 125 acres, mainly of oak, with some pine, ten to twenty years old. Trees were injured and some killed. Average loss, $1.75 per acre; total, $218.

31. May 8th. At Fairton, a farmer burning brush burned and killed 300 acres of very thrifty oak and pine timber, fifteen years old. Average loss, $6 per acre; total, $1,800.

32. April, 1902. A mile east of Bridgeton, a farmer burned off a small lot on a windy day. The fire spread to 800 acres of excellent oak and pine timber, thirty years old, which was killed for the greater part. Average loss, $20 per acre; total, $16,000.

33, 34, 35, 36. April, 1902. Four fires in the interior of Landis township were all caused by men clearing land. According to information from reliable persons in Vineland, 2,000 acres of young pines and oak were destroyed. The damage is estimated at an average of $5 per acre; total, $10,000.

CAMDEN COUNTY.

37. April, 1902. Near Winslow Junction, locomotive sparks or coals set fire to 400 acres of pine timber, fifty years old. Average loss, $15 per acre; total, $6,000.

GLOUCESTER COUNTY.

38. April, 1902. One mile east of Clayton, a fire was started by burning brush. It burned and killed 275 acres of thrifty oak, with some scattered pine, nineteen years' growth. Average loss, $3 per acre; total, $825.

39. May, 1902. Near Downer, at Willow Grove, from burning brush, a fire spread to 400 acres of oak timber, thirty-five years old, which was killed. Average loss, $3.50 per acre; total, $1,400.

40. May, 1902. One mile southwest of Almonesson, on the "parsonage grounds," burning brush set fire to seventy-five acres, chiefly of thrifty oak, forty years old; mostly killed. Average loss, $9 per acre; total, $676.

41. May, 1902. Near Prosser's Mills, at "New Brooklyn," fire from burning brush, swept over sixty acres, chiefly of thrifty oak, forty years old. The timber was mostly killed. Average loss, $8 per acre; total, $480.

42. June, 1902. A little east of Franklinville, a fire set by a feeble-minded person, who desired to see the woods burn, devastated 120 acres of oak and some chestnut and scattered pine. This tract had been protected from fire for a long period and was from twenty to forty years old. The greater part was killed. Average loss, $7 per acre; total, $840.

MERCER COUNTY.

43. June, 1902. At Princeton Junction, burning brush set fire to fifteen acres of oak of thirty years' growth. The trees were killed. Average loss, $10 per acre; total, $150.

MONMOUTH COUNTY.

44. April, 1902. A fire started from some unknown cause near Prospect, near the road leading from Smithwood to Lakewood. It burned and killed 220 acres of oak with some pine. Average loss, $5 per acre; total, $1,100.

45. May, 1902. Near Freehold, a fire, cause unknown, swept over 400 acres of fine chestnut timber, forty years old. Average loss, $12 per acre; total, $4,800.

MORRIS COUNTY.

46. June, 1902. West of Denmark, hunters set fire to 350 acres of oak and chestnut on Green Pond mountain. The timber was thirty years old, and was killed in part. Average loss, $2 per acre; total, $700.

OCEAN COUNTY.*

47. April, 1902. Near Whitings, a fire, due to locomotive sparks, burned 1,000 acres of pine, partly seedlings, thirty-five years old, of good quality, partly scattered pine of poorer quality,

* See, also, record for Burlington county.

of five to twenty-five years' growth. The seedlings were killed, the scattered pine more or less injured. Average loss, $2 per acre; total, $2,000.

48. May 8th, 1902. Near Manchester, fire was set by smokers to 300 acres of pine of poor quality, mostly sprouts, ten to forty years old. The trees were killed. Average loss, $2 per acre; total, $600.

49. May, 1902. Northwest of Cassville, a fire was set maliciously to destroy cordwood. It burned 1,280 acres of poor quality of pine timber, fifteen years old, and 350 cords of pine cordwood. Loss on cordwood, $1.75 per cord. Average loss to standing pine, $0.75 per acre; total, $1,572.

50. May, 1902. Northeast of Cassville charcoal burners set fire to 500 acres of poor, scruby pine of little value. Average loss, $0.25 per acre; total, $125.

PASSAIC COUNTY.

51. April, 1902. At Charlotteburg, fire, set by smokers, burned and killed twenty-five acres of oak and chestnut, forty years old. Average loss, $4 per acre; total, $100.

52. April, 1902. Near Negro pond, a fire, set by hunters, burned 1,100 acres of oak and chestnut, forty to fifty years old. The trees were partly killed and partly very badly injured. Average loss, $4 per acre; total, $4,400.

SALEM COUNTY.

53. May, 1902. Near Elmer, a fire, set by burning brush, burned and killed 400 acres of oak and chestnut, thirty years old, and 120 cords of wood worth $2 per cord. The damage to the standing timber is estimated at $5 per acre; total, $2,240.

54, 55. May, 1902. Near Alloway, two small fires were caused by burning brush, but were extinguished without damage.

56. May, 1902. One-half mile west of Woodstown, a fire was set, probably by a tramp. Eighty acres of oak sprouts were badly damaged. Average loss, $3 per acre; total loss, $240.

SOMERSET COUNTY.

57, 58, 59, 60. Four small fires were started by burning brush at Far Hills, Mendham and Chester, but were observed in time and extinguished before any damage was done.

61. May, 1902. A fire at Martinsville, cause unknown, burned 100 acres of oak and chestnut timber, twenty to forty years' growth, which was partly injured. Average loss, $4 per acre; total, $400.

SUSSEX COUNTY.

62. July, 1902. Hunters started a fire near Milton which burned and killed 100 acres of oak and chestnut sprouts of ten years' growth. Average loss, $3 per acre; total, $300.

63, 64, 65. July, 1902. A fire near Colesville, caused by hunters, burned and killed thirty acres of oak and chestnut sprouts ten years' growth. Average loss, $3 per acre; total, $90. Hunters also caused two fires near Waterloo, but these were extinguished in time with very little damage.

SUMMARY.

The above statement shows that between April and September sixty-five fires occurred in fourteen counties; that 98,850 acres of timber land were burned over, with a total damage conservatively estimated at $168,323. With very few exceptions, which have been noted, absolutely no attempts were made to extinguish these fires, which were allowed to burn themselves out. The causes were as follows: Set by locomotives, 21; farmers burning brush and clearing land, 22; hunters, 6; smokers, 4; unknown, 4; charcoal burners, 3; incendiary, 2; tramp, 1; feeble-minded person, 1; accidental, 1.

A summary by counties is as follows:

Atlantic	11	fires,	11,417	acres	burned,	damage,	$32,463 00
Burlington	5	"	25,128	"	"	"	25,100 00
Cape May	13	"	1,950	"	"	"	4,705 00
Cumberland	7	"	3,225	"	"	"	28,018 00
Camden	1	"	400	"	"	"	6,000 00
Gloucester	5	"	830	"	"	"	4,220 00
Mercer	1	"	15	"	"	"	150 00
Monmouth	2	"	620	"	"	"	5,900 00
Ocean	5	"	53,080	"	"	"	54,297 00
Passaic	2	"	1,125	"	"	"	4,500 00
Morris	1	"	350	"	"	"	700 00
Salem	4	"	480	"	"	"	2,480 00
Somerset	5	"	100	"	"	"	400 00
Sussex	4	"	130	"	"	"	390 00
	66*		98,850				$169,323 00

* One fire counted in both Burlington and Ocean counties.

Notes on Basket-Willow Culture.

BY F. R. MEIER.

The cultivation of the basket willow has received most attention in Germany, France, Italy, Belgium and South Russia, but up to the present time little attention has been given it in this country, and by far the largest part of the willows used in basket manufacture is imported. In France and Germany, where the cultivation of the willow has reached the greatest perfection, it has proved so profitable that farmers do not hesitate to plant the best of their wheat land in willows. Experiments have fully demonstrated that basket willows, of the same kind and quality as the imported varieties, can be grown and marketed in this country at a great profit. There are many thousands of acres in the State, particularly in the southern portion, unfit for agriculture on which the basket willow could be grown at a handsome profit.

The Soil.—The most suitable soil for its growth is a deep, rich moist, alluvial soil, but any good clayey soil will do well, if it is sufficiently moist. Sand and gravel soils are unsuitable, however. A moist soil is essential, but they will not thrive in stagnant water. Before planting, the soil should be thoroughly worked or plowed to a depth of fourteen inches or more. This is best done in the fall, the planting being done in either the fall or early spring. The more thoroughly this preliminary working is done, the better the growth after planting.

Kinds of Willow.—In order to secure good results, only the right sort of willow should be planted. This is of more importance since there are many varieties not all equally good for basket work. A good basket willow must be a quick grower, tough and pliable, and must have no side branches. The fol-

lowing varieties are recommended: *Salix amygdalina, Salix purpurea, Salix viminalis.* All of these are in demand by basket-makers, as they are all pliable, tough and durable.

The *Salix amygdalina* is a quick grower with heavy, strong yearly roots. The color, when peeled, is very white (a good quality). The wood is in demand for heavy and very fine basket work.

The *Salix purpurea* has many thin, long, pliable shoots, without side branches and is used for fine basket work only.

The *Salix viminalis* is a good grower, even on the poorest soil, but it is not wanted for fine basket work on account of the great thickness of the shoots. It is used for rough basket work and is seldom peeled. These three varieties will satisfy the demand of any basket-maker.

Planting.—Planting is done in the fall or early spring, of cuttings taken from willows of one or two years' growth. The cuttings should each be twelve inches long and the whole should be planted vertically, the top even with the surface.

While there is some difference of opinion as to distance between rows, in general the best results are secured by close planting. The rows should be seventeen inches apart and the distance of plants in the rows five inches. Since basket willows do not reach tree-size, and the stump in the ground hardly reaches the thickness of a man's arm, this distance leaves sufficient space between the rows. In some cases they are set as close as fourteen inches, or as far apart as twenty-four. If planted as recommended above, 73,000 plants per acre are required.

While it is best to make the cuttings only a few days before planting, yet where this is not practicable, the cuttings may be kept for a month or more without harm to the sprouting power of the plant, provided they are kept under shelter and protected from excessive dryness or moisture. *They should not be kept in water.*

Cultivation.—After planting, the rows should be kept free from weeds during the spring and early summer, but no cultivation should be done after the middle of June, since after this date the tender bark of the young shoots is easily injured and the value of the sprouts greatly impaired. By the middle of September

the shoots will have attained their full growth—from five to ten feet.

Cutting.—A willow culture set out in the spring can be cut for the first time the following fall or winter. They are cut every year from November until March, the essential point being to finish cutting before the sap rises in the spring. If this is not done, the stock bleeds at the cut, and the new growth is less vigorous. Cutting is done with a sharp hook, somewhat like a reaping hook, in a clean manner, close to the ground and without splitting the stock.

Preparing for Market.—Willows are sold both peeled and unpeeled. In the latter case the cutting is best done during December and January. If, however, they are to be peeled before going to market, February is the best month in which to cut. After cutting, the shoots are gathered into bunches, and placed, butts down, in water four or five inches deep. If the water is deeper than five inches they are liable to take root and are then hard to peel.

By about the first of May the sap will begin to rise and the bark will get loose. When this occurs, the time for peeling has arrived. This should be finished by the first of June, since by that time the bark will get dry again and cling to the wood. Various instruments are used in peeling willows, the so-called "jam" or "spring tong" being probably the most simple and practicable.

After peeling, the shoots are placed on racks and dried in the open air, a process which takes only a few hours and which should be accomplished as rapidly as possible, since long exposure to the sunlight causes them to lose their white color. This must be preserved in order to get the best market prices. But peeled and dried willows may be kept safely for years in a dry, darkened room.

Life.—Under fairly favorable conditions a willow culture will last twenty-five to thirty years, but this depends largely upon the nature of the soil. The writer has seen a willow culture in France which was forty-three years old and still in excellent condition; and again he has seen one in the same locality, on unsuitable ground, which had given out in twelve years.

Cost and Returns.—The first cost *per acre* of a willow culture is estimated as follows:

Planting, 15 days' labor, at $1.50 per day..............	$22.50
73,000 cuttings, at an average cost of 70 cents per 1,000..	51.10
	$73 60

To this must be added the cost of preparing the ground. Owing to the extremely varied conditions prevailing, it is impossible to give any definite figures. The cost may range from $3 to $60 or even more per acre.

The production of a willow culture, under favorable conditions, may be estimated as follows:

Yearly yield per acre, 3,400 pounds of willows, valued from 4 to 7 cents per pound; average, 5 cents per pound..		$170.00
Cost of cutting per acre.......................	$18.00	
Cost of peeling per acre.......................	67.00	
		85.00
Profit per acre		$85.00

These figures are from actual results attained in New Jersey during the past eight years.

PART IV.

The Iron and Zinc Mines.

By HENRY B. KÜMMEL.

Copper Deposits of New Jersey.

By WALTER HARVEY WEED.

The Mining Industry.

THE IRON MINES.

BY HENRY B. KÜMMEL.

The iron-mining industry in New Jersey during the year 1902 has shown a gratifying increase in production over the figures for 1901. This result is the more satisfactory since the shortage of anthracite during the closing months of the year tended to retard the work of blast furnaces, as well as to hinder the working of the mines themselves. Inasmuch as the greater part of the ore mined in the State goes at once to furnaces under the same management as the mines, any falling off in their product is immediately felt at the mines.

Apart from the increased production for 1902, a noteworthy feature of the year's work is the favorable development at the Basic Iron Ore Company's mine near Oxford Furnace, where a large body of soft magnetite, carrying about 5 per cent. of manganese, has been found. The largely increased production of the Hibernia mines, due chiefly to the extensive series of improvements instituted several years ago and still in progress, is also worthy of mention. The work of the magnetic sorter or cobber at No. 11 shaft, Hibernia, has proven so satisfactory and economical that a similar plant is being established at No. 9 shaft.

During the year the following mines were in operation, but not all of them continuously: At Oxford Furnace, Slope No. 3 (now known as the McKinley), Washington and the Basic Iron Ore Co.; at Stanhope, the Hude; at Hurdtown, the Hurd; at Weldon, the Weldon; at Port Oram, the Irondale group; at Mt. Pleasant, the Richard; at Mount Hope, the Washington, Elizabeth and Teabo; at Hibernia, the Andover, De Camp, Upper Wood, Wharton and Beach Glen; at Ringwood, the Ringwood group.

THE BASIC IRON ORE COMPANY MINE.

The Basic Iron Ore Co., operators; R. L. Ahlis, President; Erskine Hewitt, Secretary, 17 Burling Slip, New York.

This is the mine referred to in the Report for 1901 as the Osmun-Robeson mine, located near Oxford Furnace.

During the year the new shaft was sunk to a depth of 168 feet, the first 70 feet being through glacial drift. Below this it penetrated soft "clayey" material (so-called), which contained some hard masses of rock. This material is apparently disintegrated gneiss *in situ* or the result of pre-glacial mixing of materials along a depression. Firm rock was not reached in the shaft. At 75 feet and 128 feet drifts were run to the ore body, 30 feet to the southwest.

The ore body, where cut by the upper level, had a thickness of about 40 feet from the foot wall on the east to a "horse" of coarse pegmatitic granite. Two cross-cuts made through this, at an interval of about 50 feet showed its thickness to be two and a-half feet and 30 feet, respectively. Beyond the "horse" the ore-body was found to have a thickness of about 24 feet to the hanging-wall on the west. The ore on this level has already been blocked out, preparatory to removal by the "caving" system of mining.

On the 128-foot level a main drift has been run from the shaft to the ore-body, through it and some distance into the granite "horse." Branching drifts have also been run from the main drift to the ore-body to assist in drainage. Tunnels have been run both ways from the main drift along the foot-wall and along the "horse," and one or two cross-cuts made through the ore.

The ore-body was also drifted on from an old shaft, 300 feet or more southeast of the main shaft, at the 75-foot level, and reached in about 130 feet.

Both drifts from the main shaft to the ore-body through the foot-wall rock were in thoroughly soft and decomposed gneiss, largely, if not entirely, *in situ*. In the longer drift from the old shaft some firm layers of rock were penetrated, but for most of the way the rock was also decomposed. At the upper level the granite "horse" was extremely soft and clayey, the large crystals of feldspar being almost completely kaolinized. At the lower level (128 feet) the rock is somewhat harder, although yet much

decayed. The rock of the hanging-wall, where reached on the upper levels, was likewise completely decomposed, but at the lower level it has not yet been exposed. The great thickness (70 feet) of the glacial drift, together with its unweathered character, indicates that the very deep weathering and complete decomposition of the underlying rock is due to pre-glacial disintegration. This locality is very near the extreme southern limit of the later glacial drift where the eroding power of the ice was not sufficient to remove the soft disintegrated material.

The ore-body is harder than the enclosing country rocks, but nevertheless it has been somewhat altered, and is a rather soft mixture of magnetite and limonite, averaging 45 to 50 per cent. of metallic iron, and from 4 to 7 per cent. of manganese. It runs too high in phosphorus for Bessemer steel.

Owing to the soft condition of the ore as well as of the walls and the very considerable amount of water, it is necessary to timber carefully all drifts as fast as cut. The ore is being blocked out by tunnels along the foot and hanging-walls with frequent cross-cuts from which "raises" will be made and higher drifts and cross-cuts run. After the ore is thus blocked out it will be removed by the "caving" process, beginning with the higher tiers.

All of the work during the year has been along the line of development, and the ore mined was incidental to this. Something over 8,000 gross tons were shipped to the Pequest Furnace of Messrs. Cooper & Hewitt.

THE OXFORD MINES, OXFORD FURNACE.

Empire Steel and Iron Co., Catasauqua, Pa., owners and operators. Mr. J. M. Fitzgerald, Secretary of the company, has kindly furnished the following data concerning these mines:

A central power plant has been erected during the past year to operate these mines—the Washington and McKinley (formerly known as Slope 3). The new plant consists of 750-horse power Sterling boilers, a Rand and an Ingersoll-Sergeant compressor, each of modern design and capable of compressing 2,000 feet of free air per minute to 90 pounds pressure, and the necessary inter-coolers, after-coolers, condensers, pumps, receivers, &c. The air is conveyed to the Washington mine by a 10-inch pipe nearly 4,000

feet in length, and to the McKinley mine by a 6-inch branch about 1,000 feet in length.

A new shaft is being sunk at the Washington mine to give an additional exit and to improve the ventilation. The new shaft at the McKinley mine, noted in the Report for 1901, is nearly completed and it is expected that the output will soon be much increased.

The ore producton during the year at the Washington and McKinley mines amounted to 36,758 gross tons.

HUDE MINES, STANHOPE.

Musconetcong Iron Works, Philadelphia, lessees, John S. Kennedy, Stanhope, Manager.

Mr. Kennedy reports that these mines, which were reopened in October, 1901, after a period of idleness of several years, have been worked during 1902 upon the same basis and under the same management as in 1901. The ore mined, about 8,700 tons, was all hauled to the company furnace at Stanhope.

HURD MINE, HURDTOWN.

New Jersey Ore Company, Philadelphia, lessees; T. M. Williams, Mine Hill, Manager.

During the past year mining has been restricted to two workings on the southern side of the great offset, where there are at least four shoots of ore on the northwestern limb of a synclinal fold. The bottom of the fourth shoot, mentioned in the Report for 1901, was reached at about 175 feet, and it is now being followed northeastward toward the offset. The other working has also been south of the offset and on the hanging-wall side of the old turnpike openings. Here a horizontal body of ore, located by earlier prospects, has been found to change gradually to a nearly vertical dip, as it has been opened up. About 14,000 tons of ore have been taken from these two workings during the year, and it is certainly a matter for congratulation that this old mine, from which so many hundred thousands of tons of ore have been taken, should continue to be steady, even though a small producer.

THE WELDON MINE.

Berkshire Iron Co., New York, owners. L. Lea Clark, President and General Manager; Frederick Schlueter, Secretary and Treasurer.

During the year the Weldon mine was purchased by the above company, who have operated it since March. They have also purchased the Dodge mines at Ford, N. J., two miles northward. Numerous improvements have been made on the property, both above and under ground, and more are in contemplation. Owing to a temporary shutdown caused by the coal strike and necessary development work, the production of the mine for the year has been restricted to about 4,000 tons.

IRONDALE MINES, PORT ORAM.

New Jersey Iron Mining Company, owners.

The company reports that during the past year these mines have produced over 20,000 tons, in part from the New Sterling Slope, but chiefly through the Hurd slope which now has a depth on the incline of 1,100 feet. The new "sink" on the Sterling slope has been continued a depth of 90 feet, and a leader of ore has been followed all the way.

THE RICHARD MINE, MT. PLEASANT.

Thomas Iron Company; B. F. Fackenthal, Jr., President, Easton, Pa.; Mr. James Arthur, Superintendent, Port Oram, N. J.

This mine, by its production of 102,649 gross tons, continues to hold first rank among the iron mines of the State, although during the past year the production of the Wharton mine, at Hiberia, did not fall far short of the above figures. Owing, however, to the scarcity of anthracite during the latter six months of the year the work at the Richard was considerably curtailed, so that its production fell somewhat short of its star record of 1901.

MOUNT HOPE MINES, MOUNT HOPE.

Empire Steel and Iron Co., Catasauqua, Pa., owners and operators.

Mr. J. M. Fitzgerald, Secretary of the company, has furnished the following facts concerning these mines:

The Brown slope, started in 1901 to relieve the congestion in the Taylor mine, has been deepened and will soon be in such shape as will permit the opening of several levels from it. This will increase greatly the production from the Taylor vein.

Mining was also continued in the Taylor and Elizabeth mines during the year. The production from all these mines, including a small amount from old workings on this property, amounted to 20,454 gross tons.

TEABO MINE, MOUNT HOPE.

Joseph Wharton, owner; Edward Kelly, Manager.

Mr. Kelly reports that this old mine is now being developed by Mr. Wharton. A new shaft has been sunk to a depth of 240 feet, and about 1,000 tons of ore mined during the year. In the bottom of the shaft is a vein of ore about six feet wide, which contains 60 per cent. metallic iron.

HIBERNIA MINES, HIBERNIA, N. J.

Joseph Wharton, owner and operator; Edward Kelly, Manager, Wharton, N. J.

The effect of the many permanent improvements, both on the surface and underground, which have been made during 1900 and 1901 on this valuable line of mines, has been shown in their largely increased production during the past year. This is the more striking in that the scarcity and high price of coal during the latter part of the year had a tendency to restrict the output of many of the mines of the State.

Mr. Kelly has kindly furnished the following details regarding the workings during the year 1902:

The Andover Mine (formerly the Lower Wood & Crane).—The development during the year consisted in mining out the ore in stope 23 northeast to the De Camp line and southwest to the barren ground or so-called "bed-rock" and in sinking 50 feet to a new stope, No. 24, which was started. Stope 23 was also driven 60 feet southwest through this lean ground and there opened up a body of ore from seven to nine feet thick. It is expected to continue this stope still farther to the southwest to a point directly under the main skip-road, which is about 1,000 feet distant. When this is done all the water will flow by gravity to the main pump-shaft and relieve the congested condition of No. 16 and No. 19 inclines.

De Camp Mine.—The work on this property has been principally that of sinking the new skip-way, and is now about 510 feet below tunnel level. A considerable amount of ore, however, was mined during the year through No. 4 shaft. It is intended to install on this property during the coming year one 24 by 42-inch double cylinder, direct-connected hoister, by which the output will be largely increased.

The Upper Wood Mine.—The skip-road in this property has been extended from level No. 5 to level No. 8, thus increasing its depth 190 feet, and the new level No. 8 has been opened up, the vein in the bottom of the mine having a width of six feet.

A 24 by 43-inch, double cylinder, direct-connected hoister and a battery of 250-horse power of B. & W. boilers has been installed.

Wharton Mine.—No. 9 shaft has been sunk about 90 feet during the past year and has been a steady producer of ore. Heretofore this ore has been hand-cobbed, but the results obtained by the use of the magnetic cobber at No. 11 shaft have been so satisfactory that a similar cobbing plant is now being erected for use at No. 9. In the mine the development work has been such as will result in a largely increased output next year.

No. 11 shaft has been sunk about 60 feet and considerable mining done on the different levels. The magnetic cobbing-plant at this shaft has been a decided success, enabling the operator to prepare his ore at a remarkably low cost, and with very uniform results.

No. 12, or prospecting shaft, has been sunk to a depth of 560 feet. A cross-cut 80 feet long has been driven at a depth of about 380 feet, and a vein about 7 feet wide of lean ore discovered. No

mining was done at this level, but another cross-cut is being driven at 560 feet, and at date of writing has progressed 10 feet. No marketable ore has been mined out of this shaft.

The Magnetic Separator.—This mill has been idle since November 1st, 1902, and is now being remodeled with a view of largely increasing the output at a lower cost of operation. During 1902 there were shipped from this mill 6,955 tons of concentrates and 30,100 tons of sand.

The total amount of ore mined and shipped from the various operations on the Hibernia vein in 1902 was 218,433 tons, including the product of the Separator.

THE BEACH GLEN MINES, BEACH GLEN.

Mr. Wharton surrendered his lease on this property early in the year. We are informed that later the mine was operated by the Beach Glen Mining Company, but we have not been able to obtain any further information concerning it.

RINGWOOD MINES, RINGWOOD, N. J.

Cooper, Hewitt & Co., owners.

Mr. Edward R. Hewitt reports that the Ringwood mines were operated during the past year and that 9,214 tons of ore were produced and shipped. This is a considerable falling off over the production of the previous year.

THE ZINC MINES.

Mr. James B. Tonking, the Superintendent, reports the following operations during the year 1902 at the zinc mines at Franklin Furnace, owned by the New Jersey Zinc Company.

At the northern end, or Parker mine, the work has consisted in extending the several levels in a southerly direction, as noted in former reports.

At the Taylor mine (commonly called the Buckwheat) the open work, which has consisted in removing the rock from the fold down to the tunnel level, was carried on continuously until

about November 1st, since which time little has been done. There is not now a large quantity of rock to be removed, the southwest face of the dike being exposed for two-thirds of its length on a cross-section from east to west. Only a small portion of the ore exposed by this stripping on the west leg has been removed. The slope sunk from the trap-dike on the strike of the lens on the east leg was continued to the 700-foot level, when a diagonal drift was driven so as to intersect the west leg. After continuing the same for about 200 feet in a northerly direction, a winze was sunk through to the 750-foot level, intersecting the hanging-wall of the south drift from the Parker mine. This connection between the two mines makes ventilation perfect through all of the workings.

The Trotter mine was inactive throughout the year.

The amount of ore mined during the year, most of which was sent to the mill for separation, was 209,386.18 gross tons.

The Stirling Hill mines at Ogdensburg were inactive during the entire year.

Copper Deposits of New Jersey.*

BY WALTER HARVEY WEED, GEOLOGIST, U. S. G. S.

Introduction.—The existence of copper deposits in New Jersey has been known since the earliest settlement of the country, but the record of their later working shows a disheartening succession of failures. Recent development at one locality has, however, shown a very favorable change in the mineralogical conditions of the ore-body, a change of great import not only for this particular property, but also for the many similar properties of the State. It is the object of this paper to present these facts, and to discuss their bearing not only upon the genesis of these deposits and their alterations, but to show the commercial importance of testing the truth of the conclusions by actual exploitation.

History.—The copper deposits of New Jersey were worked to a limited extent in colonial days, chiefly by short tunnels or by mere quarrying out the bunches of rich surface ores. During the New Jersey campaign, Washington and the Revolutionary army made their winter camp on Watchung mountain, near Bound Brook, and the copper seam outcropping at this locality furnished ore enough for the manufacture of a brass cannon, which was afterwards used in the siege of Yorktown. Early in the nineteenth century the Griggstown, Somerville, Plainfield and Arlington localities were known and worked. In 1824 an expert smelterman was brought over from Germany and installed and worked a smelter near Bound Brook. A few years later he operated a small furnace near Belleville, N. J., the ore coming from the Schuyler mine, which was worked at intervals for the remainder of the century. Small furnaces were built in at least a dozen different places, and were, for those days, successful. Along Watchung mountain, from Plainfield west and

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north to the Raritan river, the ore-bed was opened by tunnels and open cuts, whose dump-heaps and pits, now more or less overgrown by vegetation, are clearly recognizable. I have myself counted twenty-one of these old workings in a distance of four and one-half miles along the mountain from Chimney Rock (Bound Brook) westward, and have also seen the ruins of three smelting furnaces. The period of greatest activity in this region was from 1825 to 1850. For the thirty years succeeding, the Arlington (Belleville) was the only one worked in a commercial way. About 1880 the American Copper Company was organized and acquired various small holdings, the various woodlots of the neighborhood farmers, scattered along the front of Watchung mountain, back of Somerville and Bound Brook, and embracing the old workings mentioned above. This property was worked until 1882, when operations were suspended, as the optimistic reports of its promoters were not realized. In 1889 exploratory work was resumed upon this property and continued for several years, but it was not until ten years later that the high price of copper led to a general renewal of interest in copper properties, and this property, with others at several different localities, was reopened and work of exploration and development resumed.

The gradual passage of the carbonate and oxide ores into native copper in sinking on the ore-bed of the Somerville, N. J., mine, occurring not merely as sheets, but disseminated through the rock, is new in the history of New Jersey. If, as seems likely, this change is a permanent one, as at Lake Superior and Bolivia, it is significant of a possible new and prosperous era for the New Jersey deposits.

Distribution and Occurrence of the Copper Ores.—Copper minerals occur at many localities in New Jersey, in the crystalline rocks and throughout the red sandstone areas. In the red sandstone areas copper ores are almost universally found associated with the trap-rocks, and the deposits of past or prospective commercial importance occur only in connection with these rocks. Thus the distribution of the ores is confined to that of the Triassic rocks,* and still further limited by the occurrences of the trap intrusions and extrusions of this series.

* Copper ores also occur in the Medina red sandstone in Pahaquarry township, Warren county, where they were mined in a small way in the seventeenth century by the early Dutch settlers.—H. B. K.

The red sandstone series of New Jersey consists essentially of red shales and sandstones, with associated white and gray sandstones and shales. The series is known as the Newark formation, and it extends from Connecticut southward to Virginia. The rocks contain fossil remains, which determine its age as Triassic, and it is furthermore characterized by gigantic foot-prints of great reptiles. The rocks were deposited in shallow estuarine areas, likened to that of the bays of our coast, an origin indicated by mud cracks, raindrop impressions, and the reptilian tracks already mentioned, as well as by the character and color of the rocks themselves. Where these rocks alone occur the country is devoid of all but slight elevation.

The trap-rocks are basic igneous rocks, of very uniform chemical composition, but varying physical texture, so that they vary from the basalts of Orange (Watchung) mountain, and dolerites to diabases. The trap-rocks of the Watchung mountains have been proven to be lava-flows, contemporaneous with the sandstones. The other trap-rocks of the State, whose most familiar example is seen in the Palisades of the Hudson river, are intrusive sheets. The smaller intrusions commonly follow shaly bands and often persistently adhere to a single horizon. The rocks adjacent to such sheets show the effects of heat and steam in the baking and alteration of the sediments, but such contact metamorphism is confined to a narrow band. Both sandstones and trap-sheets are tilted at generally gentle angles and are folded in synclines and anticlines. The trap-rocks form the ridges and mountains of this part of the State, their superior hardness enabling them to resist the erosion that has carried away so large a part of the shale and sandstone areas.

The trap-rock is dark bluish gray when freshly fractured, but turns greenish on exposure. It has an even-grained compact texture and consists of abundant pyroxene (probably malacolith, an iron-lime-magnesia pyroxene low in alumina), and of plagioclase feldspar (labradorite) in part altered to prehnite. The pyroxene and an original olivine has altered to chlorite. It is this which gives the dried rock its greenish tinge. There is also some magnetite present. The analyses VII. and VIII. of the table show the Orange mountain basalt and the New Haven diabase to be rocks of essentially the same chemical composition.

Structural Conditions.—As has been frequently pointed out in the previous reports of the State Geologist, the copper ores all occur either directly under or directly over the trap-sheets. The trap-sheets are very regular and the ore bodies are equally so. The regularity of this ore-bed is shown by the fact that it is proven to underlie the trap for a distance of at least eight miles. Above the trap-rock the sandstones are impregnated, but less regularly. Thus at the Arlington property the ore does not occur in a well-defined bed or vein, though it is confined to the sandstones for fifteen or twenty feet above the trap-sheet, occurring "in pockets or bunches and seams which ramify through two thick layers of sandstone and a thin bed of shale. There are numerous (slight) faults in the deposit, and it is at these points and in connection with small trap-dikes that some of the richest ore is found." Near the contact the sandstone is very generally though slightly impregnated with copper. The grayish sandstone above the traps of Watchung mountain is similarly impregnated. The structural conditions at Griggstown and the many other localities in the State where copper is found are similar. A few true veins also exist, but so far as known they are fractures later than the ore-beds, and their filling is the result of secondary processes.

Present Condition of the Mines.—At most of the deposits the old workings are inaccessible. Long tunnels are caved in and filled with water; shafts are blocked up and filled, but the extent of the workings early in the nineteenth century is known from the records and can be inferred from the great dump-heaps of waste and low-grade ore. At present the only underground workings accessible are those of the Griggstown, Arlington and Somerville properties.

At Arlington the old Schuyler mine is now the property of the Arlington Copper Mining Company. An expenditure of nearly $250,000 has been made here since 1900, mostly in the erection of an expensive reduction plant. This money was expended under the direction of an "expert" in the installation of a plant of unique design, with good machinery, but no local metallurgical value. It is designed to treat 125 tons a day, but when run on the ore it was found that the tanks would not hold the solution and the copper would not precipitate. The present manager, Mr. Wm. McKensie, is, however, conducting experimental runs which have thus far been very successful.

The property comprises 150 acres, in part honeycombed by old workings, comprising forty-two shafts, all but one now filled, and three drain tunnels, one of which drains the mine to the 100-foot level. Two inclines have been run in from the face of the sandstone bluff overlooking the Newark meadows. One incline is 220 feet long and connects through old workings with an old shaft. The second drift is but 80 feet long.*

The American Copper Mine Company own land underlain by the ore-bed outcropping for several miles along the escarpment of Watchung mountain. Their main working is, however, three miles from Somerville, at the site of the old Bridgewater mine, where an incline shaft 1,300 feet deep on the dip has been sunk on the ore-bed, with 1,800 feet or so of drifting. The drifts are thirty feet apart, alternating on each side, thus blocking out the ground in the same manner as in coal mining. No timber is used save for a few yards near the surface, and no shattering of rock has as yet occurred, the great trap-sheet, 600 feet thick, forming a perfect roof, so that using ore pillars and a cribbing of waste for support in stoping no timber is necessary. The development work is done with power drills, the softer fissile shale beds beneath the ore being first undercut and extracted as in coal mining, leaving a breast of ore easily shot down and free from waste. The development work thus far done has blocked out a large amount of ore, but as shown later, it is low-grade, and it is only below 600 or 700 feet where the change to native copper occurs that an ore averaging 1¼ per cent. can be profitably extracted. It should be stated, however, that systematic sampling by the Mine Superintendent, shows, I am told, over 2 per cent. of copper.

The surface plant consists of a 5-drill Rand compressor with 80-horse power boiler, now running two drills and the pumps, and a hoist with 12-horse power Lidgerwood engine. The 50-ton mill is equipped with 60-horse power boiler and engine, crusher, two sets roughing rolls, drying screens, sizer and two Wilfrey tables. Experiments in leaching the oxidized ores were made, but as the ore has changed to native copper in depth and this change appears likely to be permanent, the treatment is greatly simplified.

* Annual Report of the State Geologist for 1900, pp. 209–212.

The shot-like particles of copper in the concentrate from the Wilfley tables carry 60 per cent. copper.

Nature of the Ores.—The copper ores of New Jersey are commonly the oxides, carbonates and silicate of copper, of which cuprite, malachite and chrysocolla are the most common, the black oxide, tenorite, and the blue carbonate, azurite, being rare. Associated with these ores there are sheets and masses of native copper, in joints and crevices, of both trap-rock and ore-bed. Glance (chalcocite,) commonly associated with calcite, is also found. The other sulphides are rare, bornite occurring as a secondary product in the boulders of decomposed rock of the subsoil at Chimney Rock, and chalcopyrite at Arlington and other localities as a secondary mineral filling fractures. Native silver occurs at various localities associated with chrysocolla at Arlington, Somerville and Raritan river.

The workings early in the century, sometimes several hundred feet long, were abandoned because the hand-pumps would not handle the water. So far as known, the Somerville property, known as the American mine, is the only one that has penetrated below the water level and beyond the zone of surface oxidation and alteration. For this reason the discussion of mineralogical changes, permanency of ore and its genesis, is in large part based upon the facts observed and the specimens collected at this mine. This change is of great significance inasmuch as the commercial value of these low-grade deposits depend entirely upon it.

In studying the occurrence and distribution of the ore minerals it is necessary to distinguish the normal ore content of the vein (either unaltered or in its decomposition products) from the ore of secondary fractures extending down to considerable depths. The latter carry surface-waters and carbonate ores far below their normal level, and such ores are not a normal constituent of the deposit. The ores of the upper parts of the Somerville deposit are mainly red oxide of copper in nodules and bunches in the ore-bed, with films of native copper in joint cracks. The cuprite varies considerably in luster and color; bunches of several pounds' weight occur near the surface, where it is commonly surrounded by a crust of malachite and chrysocolla, often grading into a red or green jasperoid. In passing downward along the dip the carbonates disappear and red oxide is more abundant. This, in turn, changes to an earthy orange-powder or an aggregate of

minute-needles of copper oxide, associated with native copper, the latter becoming more and more abundant in depth until no oxide is seen.

As shown by Dr. Cook* many years ago, the New Jersey copper deposits are not veins, but beds, either of sandstone above the trap-rocks, or altered shale beneath the trap-sheets. Where the trap is intrusive, as at Arlington, New Brunswick, Griggstown, &c., the adjacent rocks are more or less baked, altered by the heat of the igneous magma to contact metamorphic rocks, hornstones, &c. At Rocky Hill glance and hematite occur under conditions that suggest a hydrothermal origin, and at Arlington also the conditions indicate a reimpregnation of the overlying rocks, with subsequent slight alterations and migrations of the copper.

Occurrence of Ore at Somerville Mine.—The Watchung mountain deposits are by far the most extensive deposits of the State, and as the conditions throughout are apparently uniform, the occurrence at the American mine, near Somerville, is typical for the whole area. At Somerville the ore-bed is a dense and firm, nearly uniform, purple rock, having a texture like that of a brick on cross-fracture, and differing markedly in its massiveness and uniformity of texture from the underlying shales. This ore-bed varies from 8 inches to 2½ feet in thickness. The rock also differs markedly from the shale in color, being purplish in color, while the shale is red. This purple tint is characteristic, and even after a half century of weathering on dump-heaps is readily recognized. The earlier geologists recognized the changed appearance of the shale and assumed it to be due to contact metamorphism. It is quite possible that there has been a slight baking, for, although the evidence is conclusive that the Watchung sheets originated as lava flows, spreading out over the tidal flats or shallow reaches of a great estuary, yet the alteration which I have observed under lava-flows in the Yellowstone Park and elsewhere, is sufficient to produce the changes seen here. That this alteration is not wholly due to mere baking is shown by experiments with the underlying shale, and it is believed that later alteration has taken place. Especially interesting is the porous condition of the rock. It is permeated by a great number of gashes whose lenticular cross-sections and length have the appearance of gashes made by sticking the point of a penknife into a soft substance. Besides

* Geology of New Jersey, 1868, p. 675.

these open spaces there are many small irregular cavities. This porous texture is characteristic of both the purple rock and the white spots in it down to 1,300 feet from the outcrop.

The copper minerals are not uniformly disseminated through the ore-bed, but occur only in white spots or blotches irregularly scattered through the purple rock. In depth these spots, whose white or gray tint is in marked contrast to the purple rock, invariably carry ore, at first as oxide-dust, lining minute cavaties, later as small nuggets and pellets of native copper, disseminated through the light colored rock.

As a rule the copper partly or wholly fills these pores in the white blotches of the beds. In large part the rock of the ore-bed at 1,300 feet and below is solid, these pores being filled by calcite, the significance of which and the association of calcite and native copper, will be discussed later. Throughout most of the workings, however, not only of the American mine, but the adjacent properties, the rock of the ore-bed is distinguished by the above-mentioned pores.

The *shale* beneath the ore-bed is, where exposed by weathering, friable and soft. In the mine workings it is compact and hard, composed of different layers, which thin out abruptly, are often separated by micaceous partings and streaks, and vary in grain. Immediately beneath the ore the shale is very fine grained and dense, but shows calcite specks, and when treated with dilute acid the rock shows an abundance of pores, often irregularly round and branching, of the same shape as many of the smaller particles of native copper in the ore.

The base of the trap-rock is frequently amygdaloidal at the contact, the smaller cavities being filled by calcite, the larger sometimes with quartz, calcite, laumontite and manganocalcite.

The trap-rock at and for several inches from the contact shows considerable alteration. The rock contains many small shot amygdules of calcite the size and shape of fine birdshot. Six inches from the contact it is a nearly normal dark-gray color, greenish from chloritic staining when moist, but to the eye quite fresh and unaltered. At three inches from the contact the rock is slightly lighter, increasing gradually to a well-marked brownish line one millimetre thick at one and one-half inches from the contact. A second chocolate-colored line one-eighth of an inch from the first, with a third one-sixteenth of an inch, inside of which the lines

become indistinct and merged in a general brown staining of the rock for half an inch, with more abundant calcite amygdules. The trap for an inch from the contact is much lighter colored and shows a great abundance of calcite amygdules, mostly of irregular shape and bordered or encrusted with shells of native copper.

An examination of thin sections of the ore under the microscope shows that the purple rock, although in reality an *altered shale*, has the appearance of an altered igneous rock. In fact, from the slide alone, Professor Joseph Barrell, who has kindly examined it for me, concluded that the rock is a vitrophyric andesite, showing small broken feldspar crystals, and shreds of muscovite in a glass base stained deep red by ferric oxide. The sharp feldspar crystals in marked distinction to the isotropic groundmass seem to indicate that this rock is a chilled margin of the diabase, but comparison with thin sections of the red shales shows that this distinction is not a sure one. Moreover, the ore-bed shows micaceous partings and streaks of compact very fine grained shale, and sometimes has fossil mud cracks. Despite its physical texture, therefore, these evidences show that it is merely an altered shale. This conclusion is, moreover, sustained by a comparison of the chemical analyses of the ore-rock with those of the underlying normal shales, as shown in the table below.

The analyses given below were made by the chemist of the American Copper Company, and furnished me by the courtesy of Mr. Josiah Bond, General Manager. The first column represents the trap-rock, the fourth the ore. It will be noted that the large percentage of alumina and very slight amount of alkalies present in No. IV. shows the rock to be a normal sediment. The ore proper, that is, the white copper-bearing spots in the purple gangue, evidently result from the reducing action that produced the native copper and changed the red ferric oxide to the protoxide. Tests made in the Survey laboratory by Dr. Stokes, upon samples of these rocks, showed the presence of ferric oxide in the red and the presence of ferrous iron in the white rock, a conclusion confirmed by an examination of thin sections under the microscope.

TABLE OF CHEMICAL ANALYSES OF ROCKS, AMERICAN COPPER MINE, SOMERVILLE, N. J.

	I. Trap.	II. Shale.	III. Shale.	IV. Purple ore.	V. White ore.	VI. Ore.	VII. Basalt.	VIII. Diabase.
Silica	44.84	57.45	57.02	57.24	50.15	59.68	51.86	51.78
FeO	4.3	1.64	1.93	*6.21	3.57	6.29	8.24	8.25
Fe_2O_3	6.81	9.61	8.72	....	....	....	2.14	3.59
Al_2O_3	17.68	21.19	19.60	24.31	19.07	26.35	16.25	12.79
MgO	3.90	0.83	0.76	3.20	1.74	1.71	7.97	MnO. 0.09 NiO. 0.08 7.63
K_2O	1.36	0.63	0.75	....	Trace.	....	1.06	0.39
Na_2O	1.80	0.26	0.19	....	Trace.	....	1.54	2.14
CaO	10.70	4.00	6.78	5.80	14.64	4.18	10.27	10.70
Ignition	8.20	4.12	4.01	3.08	7.44	1.75	1.33	.63
Copper	(H_2O 8.17)	Trace.	Trace.	Trace.	†3.01	....	....	TiO_2 1.41
	....	....	....	99.84	....	....	100.28	99.89

* Iron as Fe_2O_3.
† Silver 1.9 ounce per ton.

I. Trap-rock from above ore-bed, American copper mine
II. First shale layer below ore-bed, " " "
III. Second " " " " " " "
IV. Purple rock of ore-bed, " " "
V. White spots in "
VI. Ore.
VII. Basalt—normal rock of Watchung mountain, Orange, N. J. Bull. 148, U. S. G. S., p. 80.
VIII. Diabase, West Rock, New Haven, Conn.

Analysis I. shows, in the high percentage of water and ignition and the low silica, that the rock is much altered, compared with VII., which is the normal rock at Orange. The analysis I. shows normal alumina, alkalies and lime; the iron has largely altered to the higher oxide. There is a loss of 50 per cent. of magnesia as compared with the Orange rock, and a decided loss of silica. These changes indicate a leaching of the rock by alkaline waters, and the unchanged alkalies show that there was no available chlorine or sulphur to combine with and remove them.

The shale analyses are unusual in showing no alkalies. It is normal for a slightly calcareous clay shale.

Analysis IV. represents the normal rock of the ore-bed. It shows a silica content exactly like that of the underlying shale and unlike the trap-rock. It differs from the underlying shale in having much less iron, more alumina, with considerably more magnesia. It resembles the shale in having no alkalies.

The alteration of the trap is evidently the result of normal hydrometamorphism.

Occurrence of Copper in the Ore-bed.—*Copper glance* (chalcocite,) occurs in small quantities at numerous places in the mine, mainly as a secondary product in fractures. Below the zone of oxidized ores it occurs in and with calcite in joint fractures, often associated with sheets of native copper.

The masses of white ore-bearing rock of the lower drifts (1,300 feet and 1,330 feet) also carry glance. In the purple rock surrounding the white ore the glance occurs as tiny bunches of glistening crystals, attached to the walls of the gash-like cavities. In the white ore the glance occurs in solid nucleal masses, dull on existing fracture surfaces and surrounded by sooty glance (an alteration product); a substance which has also in many instances migrated and impregnated the porous rock about the cavity. The most significant feature is, however, the presence of native copper about this altered glance, usually bordering it, and whose extremely finely divided state and manner of occurrence show it to be reduced from the glance *in situ*. In several instances these spots of native copper or of glance and copper are surrounded by a halo of bleached rock, whose width is one-half the diameter of the cavity, clearly indicating an alteration due to the product of the reactions involved in reducing glance to native copper. The glance just described is not associated with calcite, but occurs in cavities.

Glance also occurs in drusy masses and along joint fractures as a crystalline mass of calcite enclosing a mesh of very minute mossy hairs of glance. This association indicates the synchronous deposition of both materials. At present it appears as if this glance was an instance of reversible reaction, *i. e.*, native copper and calcite attacked, calcite removed, glance deposited. Later solutions attack glance, *in the white rock* and reduce it. It is especially significant that *no* native copper occurs in the red rock (*i. e.*, in presence of ferric oxide) but that it is confined to and being reduced in white rock (no ferric oxide, but ferrous iron). If this is so the cause is purely local.

Association of Native Copper and Calcite.—Native copper occurs encrusting and sheathing calcite amygdules in the trap and the similar calcite masses in the white ore. I also saw native copper pseudomorphic after crystals of calcite in the collection at

the mine. This occurrence of native copper in white bleached spots in the ore-bed is a marked characteristic of the great copper deposits of the red sandstones of Corocoro, Bolivia,* and similar features were noted in 1902 by Emmons.† Native copper pseudomorphic after calcite also occurs at Corocoro and Lake Superior.

Kemp‡ notes that the comparison drawn by early investigators between the Lake Superior and New Jersey deposits is quite significant, although there is a very great difference of age. The Lake Superior deposits do not pass into sulphides in depth, except locally, *i. e.*, at the Huron mine, copper arsenide occurred, and native copper changes to glance ninety feet down in the Mamaisne mine near Sault Ste. Marie. At Corocoro, cited above, similar ores occur.

Origin of the Copper.—The copper is believed to come from the trap-rocks, and not the shales, a theory suggested by Kemp. The evidence of this is, first, 200 assays of the basalt of the Watchung mountain sheet, made for Josiah Bond, by the most refined chemical methods, gave one-fortieth of one per cent. as the average copper contents of the basalt. Second, the nucleal contents of large trap prisms, showing no alteration, were crushed, the heavier mineral concentrated by "horning," and the result, tested for me by Dr. Hillebrand, showed an appreciable amount of copper.

Even if the New Jersey trap did not contain copper its association with the deposits is a genetic one, if the ferrous salts of the altered rock acted as the precipitating and reducing agent for the native copper, in accordance with the accepted theory for Lake Superior deposits. Van Hise, following Pumpelly and Irving, says of the occurrence of native copper about magnetite grains in the Lake Superior rocks: "It seems perfectly (p. 344, Principles, &c.), clear that the protoxide of iron in the magnetite was the reducing agent which precipitated the metallic copper. The metallic copper between the particles was doubtless precipitated by ferrous solutions furnished by the wall-rocks which in many cases are basic volcanics."

* David Forbes, Quarterly Journ. Geol. Soc., Nov., 1860, p. 41.

† Verbal communication.

‡ Ore deposits, p. 168, 2d ed.

RECAPITULATION.

Summarizing the observed facts that bear upon the discussion of origin of the Somerville deposit, we have:

The basalt is chloritized as a result of ordinary hydrometamorphism. It is vesicular in places, the cavities now filled with calcite amygdules. Native copper occurs sheathing these amygdules, in the leached and green rock an inch or two thick, next the contact, but only where the underlying rock of the ore-bed is *dense;* when it is porous the copper is absent in the basalt, but occurs in the altered shale.

The ore-bed is an altered shale beneath the basalt. It has a purple color, contains a large amount of ferric iron, and is distinguished by cavities whose shape, size, abundance and inner surface closely resemble the pores of an ordinary red brick, suggesting a slight baking of a wet silt or mud. These pores are either open or partly or wholly filled by native copper below the zone of surface alteration; filled by a loose powder of orange-colored oxide at the transition line and by normal oxides encrusted by carbonates above. This native copper and most of the oxide ore is confined to patches of white bleached parts of the ore-bed, irregularly distributed. In depth the cavities of the white ore are filled by calcite sheathed by native copper, but other parts of bed show fresh glance crystals in cavities in the purple ore and altered glance and native copper reduced from it, in cavities in the white ore. The latter are surrounded by a halo of whitened gangue. The sheet copper of these bottom workings occurs in joints parallel to bedding and near the trap contact; the native copper lies alongside of layers of black calcite, consisting of calcite shot through with minute spicules and mossy fibers of glance.

These facts are believed to show that the copper comes from the basalt; that the solutions carrying it contained alkaline carbonates, and precipitated copper and glance with calcite. If the copper came from decomposing chalcopyrite of either the shale or basalt the solution would be acid and calcite attacked. Where organic matter, such as plant remains, occurred the copper sulphide would be reduced to native copper.

The glance and calcite associated together in joints and frac-

tures are regarded as secondary because they appear to be connected with a fault fracture permitting access of surface waters to the deeper workings along this fracture, and the deposits are confined to this fault and its proximity. They are regarded due to secondary enrichment. Concerning the glance in the pores of the ore-bed, I am uncertain, but believe it is primary. It is hard to see how any single chemical sequence can account for facts apparently so contradictory, and it may be like Vogt's Norwegian cases, an example of reversed conditions. The following appears to be the sequence of events:

(*a*) The basalt is chloritized and the iron reduced from silicate to ferrous oxide; (*b*) calcite amygdules formed in the basalt and pores of the altered shale bed; (*c*) copper is dissolved out by percolating waters and migrates toward the porous ore stratum beneath; (*d*) copper and calcite are deposited in the pores of the ore; (*e*) glance is reduced and ferric oxide is reduced in white patches.

The readiest reagent at hand to reduce the glance to native copper is humic acid in waters containing oxygen.

$$Cu_2S + C + H_2O + 5O = 2Cu + H_2SO_4 + CO_2.$$

There is no doubt that in some cases carbonaceous matter has produced a direct reduction of the sulphide to the native metal.

From the complete absence of iron oxide with the copper ore, and from the fact that the native copper occurs *only* in those portions of the ore-bed in which the ferric oxide has been reduced, a phenomenon common to Bolivian and European deposits as well as these, it is evident that the commonly accepted explanation is not only not adequate, but contrary to the observed facts. If it were the protoxide of iron or of magnetite ferrous solutions that caused the reductions we should have red spots and *ferric* oxide, one of the most insoluble and stable of substances, associated with the native copper. Moreover, the very common association of calcite quartz, chlorite and epidote observed in Appalachian* deposits, Lake Superior† and Oregon‡ show a genetic relation, which in connection with the fact of occurrence, show that carbonated meteoric waters traversing basic igneous rocks, carry silica, carbonate of lime and ferrous salts in solution, together with copper

*** Weed, Types Southern Copper Deposits. Tran. A. I. M. E., 1900.**

† Pumpelly, A. J. Sci., 1871.

‡ Lindgren, Geol. Blue Mtns., Oregon. Ann. Rept. Geol. Survey, 1901.

present as CuO. This is reduced by waters holding humic acid and free oxygen, producing the mineral mentioned.

Conclusions.—The commercial importance of these New Jersey deposits depends upon the cost of mining and extraction. The labor conditions and cost of supplies are considerably more favorable than in the Lake Superior region and the ore is more easily crushed. The metal occurs native in the lower workings, but the existing work does not furnish conclusive proof that this will not change to glance in depth. If it does not so change, and the average tenor of the ore proves over 1¼ per cent. and the copper native and concentrating readily on Wilfrey tables, there is a bright future for the properties when worked on a very large scale. Before erecting large reduction works it is absolutely necessary to explore and open up sufficient ground to permit of the steady extraction of a large quantity of ore daily. This underground work will also test the character of the ore and solve any doubt as to the continuance of the disseminated native copper in depth.

Mineral Statistics

For the Year 1902.

IRON ORE.

The total production of the mines, as reported by the several mining companies, was 443,728 tons.*

The total shipments from mines in the State, as reported by the railway companies, to the office of the Geological Survey, plus a small amount hauled by wagons to furnaces, amounted to 399,984 tons.

The table of statistics is reprinted, with the total amount for 1902 added.

TABLE OF STATISTICS.

Year.	*Iron Ore.*	*Authority.*
1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000 tons	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.
1864	226,000 tons	Annual Report State Geologist
1867	275,067 tons	" " "
1870	362,636 tons	U. S. census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons†	" " "
1877	315,000 tons†	" " "
1878	409,674 tons	" " "
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "

*A small amount mined at the Beach Glen and one or two other mines is not included, as reports have not been received.

† From statistics collected later.

Year.	*Iron Ore.*	*Authority.*
1885	330,000 tons	Annual Report State Geologist.
1886	500,501 tons	" " "
1887	547,889 tons	" " "
1888	447,738 tons	" " "
1889	482,109 tons	" " "
1890	552,996 tons	" " "
1891	551,358 tons	" " "
1892	465,455 tons	" " "
1893	356,150 tons	" " "
1894	277,483 tons	" " "
1895	282,433 tons	" " "
1896	264,999 tons	" " "
1897	257,235 tons	" " "
1898	275,378 tons	" " "
1899	300,757 tons	" " "
1900	342,390 tons*	" " "
1901	401,151 tons	" " "
1902	443,728 tons	" " "

* The figures, 407,596 tons, given in the report for 1900, included 75,206 tons of crude material, which should have been reduced to its equivalent in concentrates.

ZINC ORE.

The production of the New Jersey Zinc Company's mines is reported by Mr. James B. Tonking, Superintendent, to be 209,386 gross tons of zinc and franklinite ore. It was chiefly separated at the company's mills. The amount of separates and ore shipped by the railroad is reported to be 192,192 gross tons. Both reports show a gain in production over 1901.

The statistics for a period of years are reprinted from the last annual report.

ZINC ORE.

Year.	*Zinc Ore.*	*Authority.*
1868	25,000 tons†	Annual Report State Geologist.
1871	22,000 tons†	" " "
1873	17,500 tons	" " "
1874	13,500 tons	" " "
1878	14,467 tons	" " "
1879	21,937 tons	" " "
1880	28,311 tons	" " "
1881	49,178 tons	" " "
1882	40,138 tons	" " "

† Estimated for 1868 and 1871. Statistics for 1873-1890, inclusive, are for shipments by railway companies. The later reports are from zinc-mining companies.

Year.	*Zinc Ore.*	*Authority.*		
1883......	56,085 tons......	Annual Report	State	Geologist.
1884......	40,094 tons......	"	"	"
1885......	38,526 tons......	"	"	"
1886......	43,877 tons......	"	"	"
1887......	50,220 tons......	"	"	"
1888......	46,377 tons......	"	"	"
1889......	56,154 tons......	"	"	"
1890......	49,618 tons......	"	"	"
1891......	76,032 tons......	"	"	"
1892......	77,298 tons......	"	"	"
1893......	55,852 tons......	"	"	"
1894......	59,382 tons......	"	"	"
1895*				
1896......	78,080 tons......	"	"	"
1897......	76,973 tons......	"	"	"
1898......	99,419 tons......	"	"	"
1899......	154,447 tons......	"	"	"
1900......	194,881 tons......	"	"	"
1901......	191,221 tons......	"	"	"
1902......	209,386 tons......	"	"	"

* No statistics were published in the Annual Report for 1895.

Publications.

The demand for the publications of the Survey is continuous and active. So far as possible requests for the reports are granted.

It is the wish of the Board of Managers to complete, as far as possible, incomplete sets of the publications of the Survey, chiefly files of the Annual Reports in public libraries, and librarians are urged to correspond with the State Geologist concerning this matter.

By the act of 1864 the Board of Managers of the Survey is a board of publication, with power to issue and distribute the publications as they may be authorized. The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed by the State Geologist to libraries and public institutions, and, as far as possible, to any who may be interested in the subjects of which they treat.

Five volumes of the Final Report series have been issued. Volume I., published in 1888, has been very scarce for several years, but all the valuable tables were reprinted in an appendix of Volume IV., which can still be supplied.

The appended list makes brief mention of all the publications of the present Survey since its inception in 1864, with a statement of the editions now out of print. The reports of the Survey are distributed without further expense than that of transportation. Single reports can usually be sent more cheaply by *mail* than otherwise, and requests should be accompanied by the proper postage as indicated in the list. Otherwise they are sent *express collect.*

The maps are distributed only by sale, at a price, 25 cents per sheet, to cover cost of paper, printing and transportation. In order to secure prompt attention requests for both reports and maps should be addressed simply "State Geologist," Trenton, N. J.

CATALOGUE OF PUBLICATIONS.

GEOLOGY OF NEW JERSEY. Newark, 1868, 8vo., xxiv+899 pp. Out of print.

PORTFOLIO OF MAPS accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.

2. Triassic formation, including the red sandstone and trap-rocks of Central New Jersey; colored. Scale, 2 miles to an inch.

3. Cretaceous formation, including the greensand-marl beds; colored. Scale, 2 miles to an inch.

4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.

5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.

6. Map of the Ringwood iron mines; printed in two colors. Scale 8 inches to 1 mile.

7. Map of Oxford Furnace iron-ore veins; colored. Scale, 8 inches to 1 mile.

8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile.

A few copies are undistributed.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for fire-brick, pottery, &c. Trenton, 1878, 8vo., viii+381 pp., with map.

A PRELIMINARY CATALOGUE of the Flora of New Jersey, compiled by N. L. Britton, Ph.D. New Brunswick, 1881, 8vo., xi+233 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi+439 pp. Very scarce.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part I. Mineralogy. Botany, Trenton, 1889, 8vo., x+642 pp. (Postage, 25 cents).

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton, 1890, 8vo., x+824 pp. (Postage, 30 cents).

REPORT ON WATER-SUPPLY. Vol. III. of the Final Reports of the State Geologist. Trenton, 1894, 8vo., xvi+352 and 96 pp. (Postage, 21 cents).

REPORT ON THE PHYSICAL GEOGRAPHY of New Jersey. Vol. IV. of the Final Reports of the State Geologist. Trenton, 1898, 8vo., xvi+170+200 pp. (Postage, 24 cents).

REPORT ON THE GLACIAL GEOLOGY of New Jersey. Vol. V. of the Final Reports of the State Geologist. Trenton, 1902, 8vo., xxvii+802 pp. (Sent by express, 35 cents if prepaid, or charges collect).

BRACHIOPODA AND LAMELLIBANCHIATA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates XXXV. and Map. (Paleontology, Vol. I.). (By express).

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1892, quarto, pp. 402, plates L. (Paleontology, Vol. II.). (By express).

ATLAS OF NEW JERSEY. The complete work is made up of twenty sheets, each 27 by 37 inches, including margin, intended to fold once across, making the leaves of the Atlas 18½ by 27 inches. The location and number of each map are given below. Those from 1 to 17 are on the scale of one mile to an inch.

No. 1. Kittatinny Valley and Mountain, from Hope to the State line.
No. 2. Southwestern Highlands, with the southwest part of Kittatinny valley. Out of print at present.
No. 3. Central Highlands, including all of Morris county west of Boonton, and Sussex south and east of Newton.
No. 4. Northeastern Highlands, including the country lying between Deckertown, Dover, Paterson and Suffern. Out of print at present.
No. 5. Vicinity of Flemington, from Somerville and Princeton westward to the Delaware. Out of print at present.
No. 6. The Valley of the Passaic, with the country eastward to Newark and southward to the Raritan river.
No. 7. The Counties of Bergen, Hudson and Essex, with parts of Passaic and Union. A revised edition is being prepared.
No. 8. Vicinity of Trenton, from New Brunswick to Bordentown.
No. 9. Monmouth Shore, with the interior from Metuchen to Lakewood.
No. 10. Vicinity of Salem, from Swedesboro and Bridgeton westward to the Delaware.
No. 11. Vicinity of Camden, to Burlington, Winslow, Elmer and Swedesboro.
No. 12. Vicinity of Mount Holly, from Bordentown southward to Winslow and Woodmansie.
No. 13. Vicinity of Barnegat Bay, with the greater part of Ocean county.
No. 14. Vicinity of Bridgeton, from Allowaystown and Vineland southward to the Delaware bay shore.
No. 15. Southern Interior, the country lying between Atco, Millville and Egg Harbor City.
No. 16. Egg Harbor and Vicinity, including the Atlantic shore from Barnegat to Great Egg Harbor.
No. 17. Cape May, with the country westward to Maurice river.
No. 18. New Jersey State Map. Scale, 5 miles to an inch. Geographic.
No. 19. New Jersey Relief Map. Scale, 5 miles to the inch. Hypsometric.
No. 20. New Jersey Geological Map. Scale, 5 miles to the inch. At present out of stock.

The maps comprising THE ATLAS OF NEW JERSEY are sold at the cost of paper and printing, for the uniform price of 25 cents per sheet, either singly or in lots. *Payment, invariably in advance.*

TOPOGRAPHIC MAPS, NEW SERIES.

The new series topographic maps of the Survey, on a scale of one inch to 2,000 feet, are sold at 25 cents per sheet. The following sheets are ready: HACKENSACK, PATERSON, JERSEY CITY, NEWARK, MORRISTOWN, ELIZABETH, PLAINFIELD, CAMDEN, MOUNT HOLLY, WOODBURY, TAUNTON, AMBOY, NAVESINK, LONG BRANCH, ATLANTIC CITY and TRENTON, EAST. The NEW YORK BAY and SHARK RIVER sheets will be issued shortly. They may be had by addressing the State Geologist, Trenton, N. J., with remittance for amount of order.

ANNUAL REPORTS.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo., 24 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1865. Trenton, 1866, 8vo., 12 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, on the Geological Survey of New Jersey, for the year 1866. Trenton, 1867, 8vo., 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year of 1867. Trenton, 1868, 8vo., 28 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1869. Trenton, 1870, 8vo., 57 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps. Very scarce.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1872. Trenton, 1872, 8vo., 44 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1873. Trenton, 1874, 8vo., 128 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1874. Trenton, 1874, 8vo., 115 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1875. Trenton, 1875, 8vo., 41 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1876. Trenton, 1876, 8vo., 56 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1877. Trenton, 1877, 8vo., 55 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1878. Trenton, 1878, 8vo., 131 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1879. Trenton, 1879, 8vo., 199 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1880. Trenton, 1880, 8vo., 220 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1881. Trenton, 1881, 8vo., 87+107+xiv. pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1882. Camden, 1882, 8vo., 191 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp. Scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

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* These reports can be supplied only to libraries.

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8vo., 254 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo., 45 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo., 87 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo., 112 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1890. Trenton, 1891, 8vo., 305 pp., with maps. (Postage, 10 cents).

ANNUAL REPORT of the State Geologist of New Jersey for 1891. Trenton, 1892, 8vo., xii+270 pp., with maps. (Postage, 10 cents). Scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1892. Trenton, 1893, 8vo., x+368 pp., with maps. (Postage, 10 cents). Very scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x+452 pp., with maps. (Postage, 18 cents).

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo., x+304 pp., with geological map. (Postage, 11 cents).

ANNUAL REPORT of the State Geologist of New Jersey for 1895. Trenton, 1896, 8vo., xl+198 pp., with geological map. (Postage, 8 cents).

ANNUAL REPORT of the State Geologist of New Jersey for 1896. Trenton, 1897, 8vo., xxviii+377 pp., with map of Hackensack meadows. (Postage, 15 cents).

ANNUAL REPORT of the State Geologist of New Jersey for 1897. Trenton, 1898, 8vo., xl+368 pp. (Postage, 12 cents).

ANNUAL REPORT of the State Geologist for 1898. Trenton, 1899, 8vo., xxxii+244 pp., with Appendix, 102 pp. (Postage, 14 cents).

ANNUAL REPORT of the State Geologist for 1899 and REPORT ON FORESTS. Trenton, 1900, 2 vols. 8vo., Annual Report, xliii+192 pp. FORESTS, xvi+327 pp., with seven maps in a roll. (Postage, 8 and 22 cents).

ANNUAL REPORT of the State Geologist for 1900. Trenton, 1901, 8vo., xl+231 pp. (Postage, 10 cents).

ANNUAL REPORT of the State Geologist for 1901. Trenton, 1902, 8vo., xxviii+178 pp., with one map in pocket. (Postage, 8 cents).

ANNUAL REPORT of the State Geologist for 1902.

* These reports can be supplied only to libraries.

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Compliments of

HENRY B. KÜMMEL,

State Geologist,

TRENTON, N. J.

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BOARD OF MANAGERS.

HIS EXCELLENCY FRANKLIN MURPHY, Governor and *ex-officio* President of the Board, ... Trenton.

Members at Large.

		Terms expire.
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State Geologist.

HENRY B. KÜMMEL.

To His Excellency Franklin Murphy, Governor of the State of New Jersey and ex-officio President of the Board of Managers of the Geological Survey:

SIR—I have the honor to submit my Annual Report upon the work of the Geological Survey for the year 1903.

Yours respectfully,

HENRY B. KÜMMEL,

State Geologist.

TRENTON, N. J., December 22, 1903.

ADMINISTRATIVE REPORT.

Administrative Work.—Topographic Work.—Surface Geology.—Paleontology.—Clays and the Clay Industry.—Glass, Molding and Furnace Sands.—Passaic Valley Drainage.—Drainage of the Hackensack and Newark Tide Marshes.—Forestry Work.—Co-operation with the U. S. Geological Survey.—U. S. Department of Agriculture.—The St. Louis Exposition.—Library.—Publications.

Administrative Report.

BY HENRY B. KÜMMEL, STATE GEOLOGIST.

A summary of the work of the Geological Survey for the year ending October 31st, 1903, is herewith presented in the Administrative Report, while the accompanying papers give in fuller detail some of the scientific results.

The administrative work of the Survey demands a considerable portion of my time. This work includes answering letters of inquiry regarding the resources of the State, supervision of all expenditures, editorial work upon reports, supervision of the distribution of reports, of the proper care and classification of the Survey collections, as well as the direction of the scientific investigations. In much of this work most efficient aid has been rendered by Miss Laura Lee, whose familiarity with the office routine has relieved me of many details.

A long and severe illness during the latter part of the year compelled me to relinquish entirely all work. In this emergency the Board of Managers requested former State Geologist Dr. John C. Smock to assume control, which he kindly consented to do. Dr. Smock not only gave attention to the routine work, but also very kindly undertook the major part of the preparation of the Annual Report, so that when I was able to resume my duties late in December I found only a few paragraphs of the Administrative Report needing to be written. My thanks are also due to other members of the Survey staff, particularly to Mr. G. N. Knapp and to Miss Lee, for their efficient services in the office work during my absence.

During the year the mailing list has been revised and partly rewritten, and the photographic negatives and prints have been classified both geographically and geologically.

My scientific work during the year has been partly in the field and partly in the office. Several weeks were spent in the field in collecting additional data regarding the clay deposits and in completing the detailed clay map in the vicinity of South Amboy and Matawan, as well as in visiting numerous localities in the northern part of the State. A few days were also spent with Mr. Knapp and with Dr. Weller in their work upon the formations in the southern part of the State.

In the office the scientific work has been as follows. The Annual Report for 1902 was compiled and proofs read. The Report on Paleozoic Paleontology, Vol. III, by Dr. Weller, was read in manuscript and afterwards in proof. That portion of the Report on Clays which relates to the stratigraphy of the clay-bearing formations was written and Dr. Ries' portion of the manuscript was also read. Maps to accompany this report were prepared. Some time was also spent in preparing maps and manuscript for two geological folios to be published in cooperation with the United States Geological Survey.

TOPOGRAPHIC WORK.

The topographic work has been, as heretofore, directed by Mr. C. C. Vermeule, who has been assisted at various times by Messrs. P. D. Staats, W. A. Coriell, J. F. Scrimshaw, G. A. Johnson and Robert Allen.

At the beginning of the year many of the sheets of the Atlas of New Jersey—scale, one inch per mile—were out of print, so that new editions were necessary. This fact has given opportunity for extensive revisions, particularly in the vicinity of the important cities, thus bringing the maps down to date. It also raised the question whether the old system of overlapping sheets was the best which could be adopted. Correspondence with a number of the largest purchasers of these maps showed an almost unanimous opinion that a system of non-overlapping sheets,

matching edge to edge, and arranged in tiers across the State, would be better than the present system. It was determined, therefore, to replace the old sheets as rapidly as the editions on hand became exhausted by new sheets, practically the same size and on the same scale, but somewhat differently arranged. The new sheets will be numbered from 21 to 37 inclusive, and when the entire substitution has been made they will take the place of the old sheets 1 to 17. At the present time Nos. 2, 4, 5, 7, 11 and 12 of the old series are out of print and can no longer be supplied. Nos. 22, 24, 26 and 27 of the revised sheets have already been issued, and sheets 31 and 32 will be published shortly. In large part these revised new sheets cover the same territory as those which are out of print.

The necessary field revision, the preparation of copy for the engraver and the reading of proofs of these sheets has engaged the attention of the topographic force. In addition the proofs of the Shark River sheet and the New York Bay sheet of the large scale maps were examined and corrected.

Mr. Vermeule's office force has also spent considerable time in preparing drawings to illustrate the Annual Report for 1902, as well as the Clay Report.

During the coming year it is proposed to continue the revision of the older maps, particularly of sheet 8 and 17, editions of which will probably be exhausted at the end of the year. Sheet 8 will be replaced by No. 28, covering nearly the same ground, and sheet 17 in part by 37.

SURFACE GEOLOGY.

Prof. R. D. Salisbury has continued in charge of the Surface or Pleistocene work. He was in the field for a short time in June.

Mr. G. N. Knapp, working as Mr. Salisbury's assistant, began field work in April and, with the exception of a few weeks in September, was engaged in these investigations until late in October. His work was chiefly in Burlington, Mercer, Middlesex and Monmouth counties, and the detailed revision of the mapping of the surface formations commenced the year previous was com-

pleted. Incidental to the work upon the surface sands and gravels the mapping of the underlying formations—chiefly the sands, clays and marls of Cretaceous age—was revised so that the Survey now has data on hand for a correct map of the Cretaceous formations on a scale of one mile to an inch. After the field season, Mr. Knapp compiled his field data and wrote up his results.

The preparation of a monograph upon the Surface geology of South Jersey, comparable in scope to the Report upon the Glacial Geology, needs now to be undertaken. Great interest has been aroused by the "Glacial Geology," and frequent requests for it are received from all classes of citizens and from all parts of New Jersey, as well as from citizens of other States. This interest warrants the preparation of a companion volume upon the southern counties. Probably no previous report of the Survey has ever been so widely read, over 3,300 copies being distributed, chiefly in answer to requests, and its publication has undoubtedly done more to bring the work of the Survey to the notice of the public than any other work, except perhaps the publication of the topographic maps.

Mr. Salisbury will begin the preparation of the new report during the coming year.

PALEONTOLOGY.

The paleontological work of the Survey in the division of invertebrate fossil forms has been in charge of Dr. Stuart Weller. During the early part of the year he supervised the publication of his report upon the Paleontology of the Paleozoic formations, Vol. III of the Paleontology series. Later in the year he commenced the study of the fossils found in the sands, clays and marls of the southern portion of the State. He was in the field from July 16th to September 9th and examined the Cretaceous formations in Monmouth, Burlington, Camden, Gloucester and Salem counties. The work was in the study of the stratigraphy and the collection of fossils from the various strata. A large collection of fossils was made, which will throw much light upon the range and distribution of the species when they have been

thoroughly elaborated and studied. At the time of publication of Volumes I and II of the Paleontology of New Jersey by Prof. Whitfield the data furnished with the specimens was insufficient to make them of much use in a close stratigraphic study of the Cretaceous beds. It is the purpose of his work to furnish this data and to work out the stratigraphic relations of the various species and assemblages of species or faunas.

Since the close of the field season Dr. Weller has devoted his entire time to the preparation and identification of the collections, but has not yet progressed far enough to make any final statement of results. He reports, however, that there are definitely recognizable faunal zones in the Cretaceous which can be readily traced entirely across the State, and which will constitute an efficient aid in the correlation and mapping of the strata.

It will probably be necessary to spend some time in the field during the next season in order to complete the data for the investigation.

Dr. Eastman's continued absence from this country has heretofore prevented the completion of his studies upon the Triassic fossil fish. He has now returned, however, and arrangements have been made to complete this work at once. In addition to the material collected by the Survey, he will examine and report upon material in several private collections, as well as similar forms in the larger museums of the country.

CLAYS AND THE CLAY INDUSTRY.

During the winter and spring Dr. Heinrich Ries was engaged in completing the laboratory tests and analyses for the Clay Report, and preparing his manuscript and drawings for the printer. The first draft of the report was submitted the latter part of June. Inasmuch as the complete report will be the work of several authors, considerable revision of the several parts was necessary to prevent contradictions and guard against omissions, so that there has been some delay in its completion. It was expected that the manuscript could go to the printer some time in October, but my illness further retarded its publication. This delay has not,

however, been entirely a misfortune, since there has thus been opportunity to make additional fire-tests of many clays and so increase the value of the report. Unless there are unforeseen delays the work will be issued some time during the winter.

GLASS, MOLDING AND FURNACE SANDS.

The glass sands of the State were discussed in some detail in the "Geology of New Jersey, 1868," by Dr. Cook. At that time the most extensive diggings were about three miles below Millville, on the west bank of the Maurice river. About 10,000 tons were dug annually and sold on the dock at two dollars a ton, being shipped to New York, Philadelphia and other points. It was estimated that nearly 20,000 tons were also produced at other points. In the same report a list of forty-three glasshouses was given, of which fourteen made window glass and the remainder hollow ware. Since the above report was written many changes have taken place in the glass industry. Some towns which were glass manufacturing centers twenty-five years ago have ceased to be producers, whereas other localities still continue in the front rank. At numerous places through the pine belt one may see the ruins of old glasshouses that have been so long abandoned that almost all trace of them has disappeared, only the glass refuse which marks the site of the old blast furnaces indicating their former existence. The old Lebanon Glass Works, three miles north of Woodmansie, and the old glasshouse near Manumuskin, Cumberland County, are instances of this.

Since in the early days of glass manufacture sand was dug in most instances in the vicinity of glasshouses, the distribution of these old ruins shows approximately the points at which glass sand was obtained. In these early days the sand was dug at more points than at present, but nowhere was it dug so extensively.

In not a few instances in the early days very superficial deposits of sand were used. Sometimes these were the banks or bars of sand bordering the streams, but at present no glass sand is derived from these sources. With the advent of railroad

facilities for transportation and distribution the sand industry has become localized and the largest deposits of sand which can be most cheaply worked have displaced the numerous small workings.

Inasmuch as the sand industry has been so little studied by the Survey, and since it has for many years maintained an important position among the industries of the State, a somewhat extended investigation of the character and distribution of the sands and their uses is contemplated by the Survey. As a preliminary step in this work, Mr. G. N. Knapp has collected some statistics showing the amount of sand dug in the State. Owing to the limited time available for this work, these statistics are not complete, but they give some idea of the extent of this industry, and they are therefore published.

Glass sands.—Of the eighteen glasshouses making window and bottle glass in the State, eleven establishments kindly replied to the circular letters sent out by Mr. Knapp and report an aggregate of 40,236 tons of glass sand used by them annually, of which 8,907 tons are imported and 31,429 tons are obtained in New Jersey. These figures represent probably more than half the total amount of glass sand annually consumed.

Furnace sands.—Furnace sands, variously called silica sands, fire sands and cupola sands, are used to line the steel and iron furnaces to protect their walls from the intense heat to which a continuous blast for months subjects them. These sands, therefore, are valuable or worthless as they can or can not stand up to a temperature of 2,200 to 3,000 degrees Fahrenheit and obtain a standard coherency. Statistics obtained from six of the more important sand producers show that during the past year 92,493 tons of furnace sand was dug by these firms, about 72,000 tons being sold out of the State.

Core sands.—The same six firms report the production of 59,051 tons of core sand, of which 42,500 tons were shipped to other States. This is probably only a small fraction of all the core sand annually produced in New Jersey.

Molding sand.—The annual production of molding sand as reported by six firms is 92,000 tons, of which 83,500 tons were shipped to other States.

Molding loam.—About 20,000 tons of molding loam are annually dug by these firms, 14,000 tons being sold out of the State.

Information was also sought from founders and furnaces in the State to learn amount and grades of sand used. The statistics in the following table were obtained from eighteen firms.

	Tons.	Price Average.	Price Range.	Obtained Outside State.
Molding loam, ...	10,087	$1.50	$0.50-$2.10	....
Molding sand, ...	18,752	1.50	.70- 2.30	5,549
Core sand, ...	9,613	1.25	.50- 1.75	983
Silica sand, ...	9,048	1.85	1.75- 2.50	50
Furnace sand, ...	3,125	2.50		
Shore or beach sand, ...	70	1.25		
Other grades, ...	1,210	1.00		
	51,905			6,582

The wide range in the price of the molding sands and loam is in part due to the fact that in some cases founders are able to obtain certain grades near the foundry, but must import others. For instance, one founder can obtain his loam in the adjacent fields; he gets it with his own help and his teams; it costs him fifty to seventy cents per ton, but he must ship in his core sand at $1.50 to $2.30 per ton. Another founder may be able, by virtue of his location, to obtain his core sand at fifty cents per ton and be compelled to import his molding loam for $1.50 per ton.

It is proposed during the coming season to continue these investigations and to prepare a report which shall consider not only the geographical distribution of the various grades of sand in the State, but also the chemical and physical composition, which renders one sand available for certain classes of work and another sand of similar appearance utterly useless. Such studies will include not only chemical analyses, but also physical and microscopic examinations, and to be of real value must be thorough and exhaustive.

PASSAIC VALLEY DRAINAGE.*

The great flood of October in the valley of the Passaic river; the large aggregate damages to property in the cities of Paterson and Passaic, and the studies of Mr. Vermeule on the height of the water and the extent of land overflowed and the most practicable methods of controlling these floods suggests renewed attention to the drainage plan, which was prepared by the Geological Survey and placed in charge of the Passaic Drainage Commission, but stopped by lack of the necessary funds for its completion. The several Annual Reports of the Geological Survey refer to the work done by the Commission and also to the prospective advantage of the drainage work and the desirability for its completion.

In the light of the most recent scientific investigations on the cause of malarial diseases and the agency of the mosquito in spreading them, we learn that stagnant pools of water, such as abound in the warmer months of the year on these flat lands and in the sluggish streams of this Upper Passaic valley, favor the breeding of the pestiferous insect as well as the innocuous mosquito, and, as a result, we are conversant with the prevalence of malarial disorders in the valley. The execution of the drainage plan would tend to the more rapid discharge of the lesser floods, which occur every summer, and would promote the flow of the streams and the movement of the draining-ditch waters, so that there would be much less of stagnant surface-waters and consequently little or no cause for malarial troubles. Their removal would be a great gain to the residents of the valley, and also to hillsides immediately adjoining the wet meadows in it, if not to localities further away from them. The prevalence of malaria in this valley is a most serious drawback to its improvement and

*The paragraphs in reference to this and the following topic have been prepared by Dr. J. C. Smock, whose long connection with the Geological Survey, for nearly forty years as Assistant Geologist, State Geologist and later Member of the Board of Managers, has made him thoroughly conversant with these problems and the studies undertaken by the Survey to obtain the preliminary information necessary to their amelioration.

a menace to the surrounding country, which is removable by an effective drainage system. Tillage of the soil and pasturage, which the thorough drainage would make possible in these wet lands, would not only add so much of productive wealth to the farmer, but would also make his abode healthful and attractive. The coming of the plough and the sickle mean the going of the mosquito. Of the advantages to the valley and to the State in the increase of arable land and consequent ratables it is not necessary to do more than refer to what has been said in previous reports of the Geological Survey.

The æsthetic element in the improvement by drainage deserves much greater consideration than has been given to it. All who have seen the rich polders of Holland realize what effective drainage and careful husbandry can do for the setting of the landscape. These unkempt and flood-devastated farm lands and swamps are an eyesore to the lover of rural beauty, suggesting loss of crops, waste of energy and the ills that wait on such conditions. The setting of this Passaic valley in a hill country of exceptional beauty is one of the most striking features in the topography of the northern part of the State. With so beautiful an environment it seems to be fitting that for æsthetic considerations only the drainage plan should be consummated. Man ought to complete the unfinished work of nature in draining this valley, or else restore old Lake Passaic. Not only is the valley, in its present condition, an offense to the landscape; it is productive of carelessness on the part of the farmer and consequent indifference and neglect, and this influence is felt beyond its immediate limits. Were it all in a natural condition of woodland this influence would not be of consequence or importance, but in the struggle for a pittance, or at best a livelihood, the farmer by his clearings develops conditions which are undesirable and bad examples to his fellows who live on the adjacent hillsides. The poorly-tilled farm is always a sort of nuisance among thrifty farmsteads, and this valley is not an exception. The effect of proper drainage, fully carried out in all the valley, would be on the side of order and thrift and attendant success. The moral argument for drainage is of itself worthy of consideration, if not sufficient to justify the cost of the undertaking.

The drainage plan is not inconsistent with the best protective measures which are now demanded for the protection of the cities of Paterson and Passaic. Mr. Vermeule, in his report on Floods in the Passaic in the last Annual Report of the Survey, says the results of his investigations of the floods show that "the improvements proposed by the Commissioners of Passaic Drainage would not increase, but, on the contrary, would tend to diminish the height of floods," and that there need not be any apprehension of danger from this improvement. The profiles of the river in the great floods of both 1902 and 1903 show that Beattie's dam does not exercise any controlling influence upon the height of the water during these periods. Owing to the torrential character of the streams of the upper part of the Passaic catchment basin and the flatness of the lower part, floods are inevitable and these great floods must cover these flat stretches of the valley. But it is not these extraordinarily high floods against which it is necessary to make provision by drainage, but the lower and recurring floods of every season, which run off slowly—these are to be gotten rid of by the provision of a lower dam at the Beattie Mill site and an excavated channel above the dam and the removal of the obstructions at Two Bridges. The improvements contemplated would tend to make the discharge of the floods more uniformly rapid and shorten the length of time in which the meadows would be under water during the days and weeks after the main flood has passed. As is stated by Mr. Vermeule, "the real benefits of the proposed drainage improvement do not depend on entirely preventing the overflow of the flat lands in time of great freshets. For weeks and months these lands are now saturated, not by extreme floods, but when the stream is slightly swollen, or during the tardy discharge of the waters at the end of a freshet, and it is this condition which causes sourness, prevents the raising of useful crops, and produces malarial or miasmatic diseases." The great floods probably do good in the rich sediments which the flood waters deposit in these alluvial lands, and a single flood covering them may not be altogether a disadvantage. On the contrary, the lesser floods, which recur frequently, and often during the growing season, interfere seriously with all crops and the great losses discourage the farmer.

The urgent need of some public action in controlling such floods as that of last October and that of 1902—which last year's report discussed—is recognized by all who are interested in the growth and prosperity of our cities, but the paramount interests of the cities need not be exclusive and prohibitory of improvements in the Passaic's channel at Little Falls and at Two Bridges and above in the meadows, whereby the floods shall be of shorter duration and the great and yearly losses of the farmers shall be prevented, or at least reduced greatly in amount. The city and the country can be both protected, and any plan of control which shall be equitable in its working must include in its provisions the guarding of the fields against flood, as well as the city. The last great flood appears to emphasize the need of some action by the authority of the State, and it is opportune to call attention at this time to what the State has already done through the Geological Survey and the Passaic Drainage Commission and what was proposed to be done by this plan of drainage, and further to refer again to the importance and great benefits which would result from the drainage not only to the valley of the Passaic, but to all this part of the State.

DRAINAGE OF THE HACKENSACK AND NEWARK TIDE MARSHES.

The drainage law of 1871 authorizes the Geological Survey to make surveys and plans for the drainage and improvement of tracts "subject to overflow from freshets, or which are in a low, marshy, boggy or wet condition," upon application from the owners of such tracts. An amendment to this law makes the provisions of said law applicable to tide marshes. No work in the reclamation of tide marshes has been done, nor has there been any application for the examination and survey of tide marsh lands with a view to their improvement, but on account of the great importance of the subject the Geological Survey had a survey made of the Hackensack and Newark marshes in 1896 and 1897, and the results of the survey, made by Mr. Vermeule, were published in the Annual Reports for those years. Public attention to the value of these lands had been directed so long ago as 1869

and 1870, when the successful reclamation of low-lying lands in the Netherlands was referred to by the late State Geologist, Dr. Cook, and the methods of procedure there were described in the Annual Reports of those years. It is so important a subject that it is again included among the topics of this administrative report and the reader is referred to these previous reports for full information in regard to the location, extent, natural divisions, drainage streams and rivers, depth of mud and of water in the waterways, sites for embankments, estimated cost of reclamation and the benefits of the improvements to the lands affected and to the adjacent upland territory.

In the report for 1896 the map of the meadows shows many of these facts. The new atlas sheet and topographic map No. 26, which has been published recently by the Geological Survey, shows nearly as well the location of these wet tidal lands, and to better advantage their unique setting, in a thickly-populated district, between the peninsular city, Jersey City, and Bayonne on the east, and the larger metropolis on the Passaic, including Paterson, Passaic, Newark, and the adjacent towns and cities. These meadows, about eighteen miles long and four miles wide, are intersected by the Hackensack and the Passaic rivers, and adjoin Newark bay at the south, and contain approximately 27,000 acres of land. The improvement of the meadows by the canalization of these rivers and some of the tributary creeks would afford at least 25 miles of navigable waterways, offering to commercial enterprise nearly twice as great a length of business water front. The depth of water to be had in the Hackensack and the Overpeck creek would be 12 to 15 feet, allowing access for vessels of considerable tonnage.

The agricultural value of these rich, alluvial lands would eventually be large enough to pay for their reclamation, although the gain in this valuation could not be realized until a great part of the soil had been sweetened by cultivation and amended by proper dressing with fertilizers. The costs of embanking and pumping would probably be greater than the land would bear solely for its use in agriculture or in market gardening. The nearness to markets and the railway lines and waterways makes

it valuable for crops of garden vegetables and for some of the more intensive lines of farming.

The recent discussions of the prevalence of malarial diseases in the country and cities on each side of these meadows, and the most practicable means of abating the nuisance of the mosquito, now recognized as the bearer of these malarial troubles, suggests forcibly the reclamation of these meadows and their permanent improvement as the sole effectual method whereby the mosquito plague and the consequent malaria can be gotten rid of to the great relief of the nearby cities, and this whole territory be made comfortable and healthy residential ground. It is well known that in many parts of England drainage has had the result of making the country much more healthy, and, particularly, has done away with malarial affections. In the Netherlands the polders are considered nearly as safe against malarial diseases as are the higher lands of the country. The mosquito pest is unknown there, at least in the degree of intolerable endurance which persons working in the tidal-marshes here are called upon to exercise. No other solution of the mosquito problem which has been proposed is likely to prove permanently effective, unless it be accompanied by the thorough drainage of their breeding places on these meadows and their cultivation in farms and market gardens, or by infilling and occupation by manufacturing industries or by commercial establishments. For the abatement of this nuisance of the mosquito alone it seems as if the reclamation of these meadows should be made. As a purely sanitary measure the subject is worthy of the attention of the residents of Newark and Jersey City and the other towns and cities in this valley.

Reference has been made to the best measures for accomplishing the improvement by drainage in the report of Mr. Vermeule, referred to above, and also to the relation of the Geological Survey to drainage schemes and the methods of procedure under the law of 1871 and its amendments. Whatever plan may be adopted it seems a fitting occasion to direct again attention to the subject and suggest further discussion in order to the best solution of the drainage problem as applicable to the Hackensack and Newark meadows.

FORESTRY WORK.

Mr. F. R. Meier has acted as Consulting Forester to the Survey. Application was made by the Newark Water Department for advice and assistance in the improved handling of the watershed forest, an area comprising 7,000 acres and consisting of sprout and seedling growth of broad-leaved trees.

Plans have been prepared by Mr. Meier for the entire tract, the purpose being to improve the forest by judicious cuttings, according to forestry principles, to re-stock waste places and worn-out farms and pastures by treeplanting.

The field work consisted in the collection of data for these plans and in dividing the forest into compartments of different sizes, according to the character of the growth and the natural boundaries. For each compartment recommendations were made as to the treatment. In devising a plan it was kept in view that a constant forest cover is desired for the protection of the watershed. The plan recommended the following operations:

1. Protection against forest fires, with an estimate of the cost of a fire system.

2. Improvement cuttings in the immature woods; what trees to cut and what to leave; at what age the improvement cuttings are to begin in sprout growth, and at what age in seedling growth; how often to repeat them; cost and returns of the improvement cuttings; effect of the same.

3. A series of thinnings—reproduction cuttings—in the mature woods; what trees to remove at these cuttings; over how long a period these thinnings should stretch; how to foster a young growth of new seedlings in a sprout forest (seedlings being the result of the reproduction cutting); cost and returns of these cuttings.

4. Planting of waste places with trees; what kinds to plant; methods and cost of planting.

A somewhat similar application was received from the Lambertville Water Company. Their land comprises at the present 291 acres, of which one-half is woodland and the other half farming land. It was the desire of the water company to have the

land examined and to have a plan prepared recommending what parts of the land now used for farming purposes would be more suitable for tree growth than for farming, and to recommend improved methods in handling the wood lots. A careful forest survey was made and the land more suitable for tree growth than for agriculture selected, the kind of trees and planting methods for different soils and locations were recommended and an estimate given as to the cost of the same.

The recommendations as to the cuttings were similar to those made for the Newark watershed forest.

Mr. Meier has also commenced an investigation of the cedar swamps of the State with a view of determining the amount of white cedar standing, rate of growth, age and quality, and of devising a plan whereby a valuable reproduction of young white cedar may be secured and the quantity and quality of the future stand improved. Many of the so-called white cedar swamps have been found to contain but very small amounts of this tree, the original growth having been cut off or killed by fires and a new growth of less valuable trees having taken its place. During the coming season this line of investigation will be continued.

Mr. Meier has also investigated the forest fires which occurred during the past year. Owing to the severe drought which prevailed in April and May there were numerous and extensive fires in various parts of the State. He personally inspected every burned tract and made careful estimates of the damage, based upon examination of the bark and wood of the trees in various parts of the tracts. His estimates can be accepted as reliable and conservative. His examinations show that 79 forest fires occurred during the year, distributed by counties as follows:

	Fires.	Acres Burned.	Damage.
Atlantic,	11	24,700	$75,205.00
Burlington,	7	21,925	107,394.00
Cumberland,	9	8,265	17,342.00
Cape May,	4	2,720	13,985.00
Camden,	1	7	420.00
Gloucester,	6	1,055	4,104.00
Monmouth,	2	558	3,854.00
Morris,	10	4,525	23,921.00
Ocean,	10	9,123	18,251.00

	Fires.	Acres Burned.	Damage.
Passaic,	5	1,105	3,432.00
Salem,	4	2,040	7,430.00
Somerset,	1	120	180.00
Sussex,	8	8,900	30,225.00
Union,	1	3	1.50
	79	85,046	$305,744.50

Comparing these figures with those for 1902, given in last year's report, it will be seen that there were 14 more fires, although the burned tracts measured 13,804 acres less. The damage, however, was much greater—$305,744.50, as against $168,-323, an increase of $137,321.50, or about 82 per cent. This great increase in the loss is due in part to the fierceness of the fires and also to the better class of timber burned. The greatest loss per acre was caused by the fire in Camden county, where a fine growth of white and red oak 50 years old was killed. The minimum loss per acre was $0.50 and the average loss was about $3.60. In making these estimates only the damage to the timber has been considered, no account being taken of buildings which were sometimes burned or of the indirect loss due to impoverishment of the soil by the destruction of the humus.

When we examine the causes of these fires we find that locomotives started 26, persons burning brush or grass, clearing land, etc., 21; smokers, 7; children, 6; incendiary, 3, and that the balance originated from a variety of causes. The fires caused by burning brush, etc., swept over 49,197 acres and did damage to the extent of $169,494, the loss from one fire alone in Burlington county being $105,000. Those set by locomotives caused a loss of $79,658, and covered 19,521 acres. These figures are interesting inasmuch as, in the popular mind at least, the railroad is supposed to be the chief, if not almost the only cause of our forest fires. While it is true that many fires have been started by sparks from the locomotives, yet during the past season only one-third the fires originated in this way and these caused only about one-fourth of the loss. Negligence in burning brush and grass, particularly on windy days, started one-fourth the fires, burned nearly 60 per cent. of the total acreage and did more than 50 per cent. of the damage. In view of these facts it is evident that there

is need for a more rigid enforcement of the law in reference to forest fires, particularly of those provisions which forbid the burning of brush, grass, etc., without maintaining a sufficient watch to prevent it spreading.

Methods of Prevention.—In about 50 per cent. of the fires some effort was made to extinguish them. Many of those started by locomotives were fought by railroad section gangs, and the measure of their success may be seen from the fact that the average number of acres burned by the locomotive fires was 750 acres per fire, as against 2,342 acres per fire for those caused by farmers, and 1,076 acres the average for all classes. In some cases the section gangs were slow in arriving at the fire and so were handicapped in their work, for with forest fires, as with other fires, prompt action is indispensable for successful fighting.

Several fires in Cumberland county were successfully fought by fire marshals who had been appointed by the townships, in accordance with the provisions of the law passed in 1902. Other fires were opposed by the organized force of men employed by Mr. Joseph Wharton on his large forest tract near Atco and Atsion.

In many cases back fires were started and these sometimes proved successful, but in other cases they did more harm than good through injudicious management. While it is absolutely necessary in many cases to start back fires to check a great conflagration, yet it should never be done except under proper authority, and indiscriminate back firing by private individuals should be made punishable by law.

Chapter 139, Laws of 1902, made provision for fighting fires. Cities, townships and other municipalities have been given the power to appropriate money for preventing and fighting forest fires and to appoint fire marshals. The State has obligated itself to pay annually (up to $200 and not exceeding $10,000 in all) to every city, township, or other municipality, double the amount of money appropriated by the township for fighting fires, so that townships, by an appropriation of $100 themselves, can receive $200 from the State for this purpose.

Sections 7 to 13 of the law are as follows:

"7. No person shall burn, or cause to be burned, any pit of charcoal, or shall willfully or negligently set fire to or burn, or cause to be set fire to or burned, any brush, grass, leaves or other material whereby the property of any other person is endangered or destroyed, unless he shall keep and maintain a careful and competent watchman in charge of said burning pit, brush, grass, leaves or other material, from the beginning of said fire until it is extinguished.

"8. Any person offending against any of the provisions of any of the last section of this act shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding one thousand dollars, or by imprisonment not exceeding three years, or both.

"9. Upon the application of not less than ten freeholders of any city, township or other municipality in which any forest fire has occurred, to the fire marshal, or, in case there shall be no fire marshal, then to any constable, representing that they believe an investigation of the origin and other matters pertaining to said fire should be had, it shall be the duty of said fire marshal, or constable, to apply to some justice of the peace to investigate the same, and it shall be the duty of said justice to make such investigation; for the purpose of such investigation said justice shall have power to issue subpœnas for and swear witnesses, and shall have like powers and duties as in the examination and hearing of persons brought before him charged with crime, and said investigation shall be conducted, as far as can be, in like manner thereto; the said fire marshal, or any constable, shall have power to serve all subpœnas, warrants or other papers required to be served in the course of said investigation, or of any proceedings for the arrest and commitment of any person as the result of said investigation.

"10. At the conclusion of said investigation the said justice shall make, in writing, a certificate thereof, in which he shall find and certify how and in what manner such fire happened or was attempted, and all the circumstances attending the same; if he shall find that there is evidence that the said fire probably originated from, or was fostered by, the act of any person or persons in violation of any law of this state in force at the time of said fire, he shall so certify, and who was or were guilty thereof, either as principal or accessory, and in what manner; if he shall be unable to ascertain the origin or circumstances of such fire, he shall find and certify accordingly.

"11. If the said justice shall find that there is evidence that the said fire probably originated from, or was fostered by, the act of any person or persons in violation of any law of this state, as above specified, he shall issue process for the arrest of the person or persons who have so violated such law, and may, after due examination, in his discretion, commit him or hold him to bail, to await the action thereon of the next grand jury of the county; and said justice shall also have power, when in his judgment necessary so to do, to bind over the witnesses to appear and testify at the next court of quarter sessions of the peace of said county.

"The testimony of all witnesses examined before the said justices in said investigation shall be reduced to writing by the said justice or under his direction, and shall be returned by him, together with his certificate of his said investigation, and all recognizances and examinations taken under his hand and seal to the next court of quarter sessions of the peace of said county."

In view of these provisions of the law and the fact that 21 fires were caused by persons burning brush, grass, etc., 7 by smokers, and 3 by incendiaries, it would seem that *not more law, but more enforcement of the present law is needed.* A few convictions and fines according to the above provisions would do much to prevent a large proportion of the forest fires in the State. The remedy is in the hands of the local communities. Ten freeholders of any township can compel an investigation into the origin of any fire and, where the law has been violated, can start the legal machinery for the punishment of those guilty. Even if conviction fails in some cases, as it very likely may, through local apathy, sympathy for the defendant "who did not mean to start the fire," or the indifference of the proper officials, the trouble and expense of defending a suit would prove a salutary lesson not only to the defendant himself, but to the community.

Printed notices referring to the forest laws and the penalties for their violation have in some townships been posted on trees, and serve as a reminder to the unthinking and careless that fires cannot be started with impunity.

During the past year three townships—Weymouth, in Atlantic county, and Landis and Deerfield, in Cumberland—have each appointed fire marshals, appropriated money and received State aid for this work. More of the townships should accept the provisions of this law, which, if it be strenuously enforced, will largely put an end to this annual destruction of our forests. Probably, however, many of the townships are ignorant of this law and unfortunately public sentiment in some of the townships which most need it is such that there is very little chance of its provisions being adopted, at least for many years. Although the law has not yet been fully tried and its efficacy is still in doubt, it is an open question whether an organized State force along the lines suggested in the report for 1902, and reiterated this year by Mr. Meier, will not ultimately be necessary if New Jersey is to save her forests.

The figures and statements presented by Mr. Meier relative to the forests of Europe and the subject of forest fire insurance are interesting and instructive in this connection. Under present conditions in New Jersey there is practically no incentive to the

forest land-owner in the pines belt to do anything towards improving his holdings, since there is almost a certainty that, even if he himself takes all due precautions, fires started by his careless neighbor or in the adjoining township, which has no fire marshal, will destroy his timber before it is ready for market. When the forest fire risk has been reduced to that of European countries, then there will be some inducement for the holders of large forest tracts to spend money in replanting and otherwise improving their holdings. Before the forests of the State can be of great value, *forest fires must be prevented.*

COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY.

As was noted a year ago, the United States Geological Survey is publishing a geological map of the entire country. The folios relating to New Jersey will be prepared in cooperation with the State Survey. During the past year data for mapping the distribution of the Cambrian and Ordovician rocks of the Franklin Furnace folio were prepared. The map and text of the glacial geology, also for this folio, was furnished by Mr. Salisbury of the State Survey.

Preparation of the Passaic folio was likewise commenced. The geology of the Triassic rocks—the red sandstones and traps—has been prepared conjointly by the State Geologist and Mr. N. H. Darton, of the U. S. G. S. The map of the glacial formations will be taken from data furnished by the State Survey, and this portion of the descriptive text will be written by Mr. Salisbury. The crystalline formations have been studied and described by the geologists of the National Survey, which bears all the cost of engraving the maps.

Field studies on the crystallines of Warren and Morris counties were carried on during the past season by Dr. W. S. Bayley and his assistant, working under the auspices of the U. S. Survey. As soon as these studies are completed it will be possible, with the material already collected by the State Survey on the sedimentary rocks and glacial deposits to prepare the Raritan folio, which lies next west of the Passaic.

UNITED STATES DEPARTMENT OF AGRICULTURE.

The Division of Soils of the U. S. Department of Agriculture is making a soil map of the United States. In 1901 the area covered by Sheet 10 of the Atlas of New Jersey was so surveyed and in 1902 the region east of Trenton, Sheet 8, was so mapped. This work was carried out entirely by U. S. parties in the Division of Soils. However, the atlas sheets of the New Jersey Geological Survey were used in their field work, and both maps as published were printed from transfers furnished by the State Survey from its engraved stones.

THE ST. LOUIS EXPOSITION.

Late in the summer the St. Louis Exposition Commissioners appropriated $5,000 for the preparation of a geological exhibit of New Jersey's natural resources, and requested the State Geologist to prepare it. Mr. S. H. Hamilton, who had had considerable experience in museum work, was engaged to take active charge of this work and commenced his labors September 1st. Eight months is none too long a time to prepare, pack, ship and install a creditable exhibit, and Mr. Hamilton has had much to do. A plaster-of-paris reproduction of the Hadrosaurous skeleton found years ago at Haddonfield, the bones of which are now in the Museum of the Philadelphia Academy of Sciences, will be a central feature of the exhibit.

Suites of specimens showing the geological series of rocks as represented in New Jersey, the minerals, the metals and ores, the clays, marls, sands and other economic resources will be another marked feature. Illustrations, photographs, transparencies and maps will make known the attractiveness of New Jersey scenery, the distribution of her resources and the importance of her industries. After the close of the Exposition the material will be available for exhibit in the State Museum. The work has been greatly facilitated by the hearty cooperation of several citizens of the commonwealth and by the courtesies extended by officials of the larger museums in the East.

LIBRARY.

During the year the Survey library received by exchange and purchase 48 bound volumes, 156 unbound volumes, 113 pamphlets and 337 maps.

PUBLICATIONS.

The Report on Glacial Geology, Volume V, of the Final Report series, pp. xxvii + 802, plates 56, figures 102, was issued early in the year. It aroused a deep interest in this phase of geology and the demand for it was for several weeks much greater than the mailing department of the Survey could supply. During the year 3,394 copies were distributed.

The Annual Report for 1902, pp. viii + 155 and 8 plates, was published in March and distribution was at once begun, 3,368 copies being sent out during the year.

In April Dr. Weller's report, Paleozoic Paleontology, Vol. III, was issued. Owing to the highly technical character of this report it was sent only to those who requested copies, and 675 were distributed.

Requests for previous reports are constantly being received, both from libraries and individuals, and, so far as possible, these are granted. It is impossible, however, to furnish all the reports, since many are out of print, and of some others the supply is so low that discrimination is necessary to insure the few remaining copies going to persons who will make the best use of them. The appearance of Vol. V caused a brisk demand for the previous volumes, of which II, III and IV could be supplied. So, too, Paleontology III brought many inquiries for Vols. I and II of the Paleontological series. Of the earlier reports—annuals and finals—there were distributed during the year about 3,000 copies, making a total of about 10,400 volumes distributed. The stock of several of these reports, notably Vols. I and IV and Annuals 1891, 1892, 1893, is so far depleted that it is not possible to grant indiscriminate requests for them.

Of the large scale maps, 2,000 feet to an inch, the Shark River sheet was issued in April and the New York bay sheet in June and put on sale.

Of the new one-inch-per-mile maps, Sheet 4 has been displaced by Sheet 22, Sheet 2 by No. 24, and Sheet 5 by No. 27. All these sheets were revised in the vicinity of the important towns before publishing the new editions. So many changes had occurred in the vicinity of Newark and Jersey City that it was found necessary to engrave entirely new stones, rather than to attempt to alter the old ones. This work was nearly completed at the close of the year, and Sheet 26, which replaces No. 7, was issued early in December of the new year.

During the year 808 copies of the one-inch-per-mile sheets and 1,381 copies of the large scale maps were sold, a total of 2,189 sheets.

PART I.

Report on a Proposed Tide Waterway Between Bay Head and Manasquan Inlet.

By C. C. VERMEULE.

INTRODUCTION.

The One Hundred and Twenty-seventh Legislature at its session in 1903 passed the following act, in accordance with which the accompanying report is submitted:

CHAPTER 129, LAWS OF 1903.

An Act making an appropriation for surveying a waterway to connect Barnegat bay with Manasquan inlet, for the reclamation of oyster and clam lands in upper waters of said bay.

WHEREAS, It is represented to the Legislature that all the upper part of said bay formerly bearing oysters and clams is now barren through the closing of Cranberry inlet;

WHEREAS, Thousands of acres would resume producing oysters and clams if salt water were re-introduced therein;

WHEREAS, The said lands now contain shells in abundance, making them immediately available without the expense of shell planting;

WHEREAS, It is deemed feasible to connect said Manasquan inlet with Bay Head by a tide waterway; therefore,

BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey:*

1. The sum of one thousand dollars, or so much thereof as may be necessary, be and the same is hereby appropriated out of the state fund for the use and purpose of making a survey for a tide waterway between Bay Head and the Manasquan inlet, said sum to be used for the purpose of defraying the expenses of the engineer in making the survey and estimates of the cost of said work and the manner in which it shall be done; the said survey to be under the control and supervision of the board of

managers of the geological survey, this appropriation to be available at the same time and in the same manner as the usual appropriations are made and available for the fiscal year, and that upon the completion of the said survey and estimates the report of the engineer selected by the said board shall be forthwith made to the said board, and the said board shall transmit said report with such recommendations as it may see fit, looking towards the construction of said waterway, in the annual report of said board to the governor of the state of New Jersey.

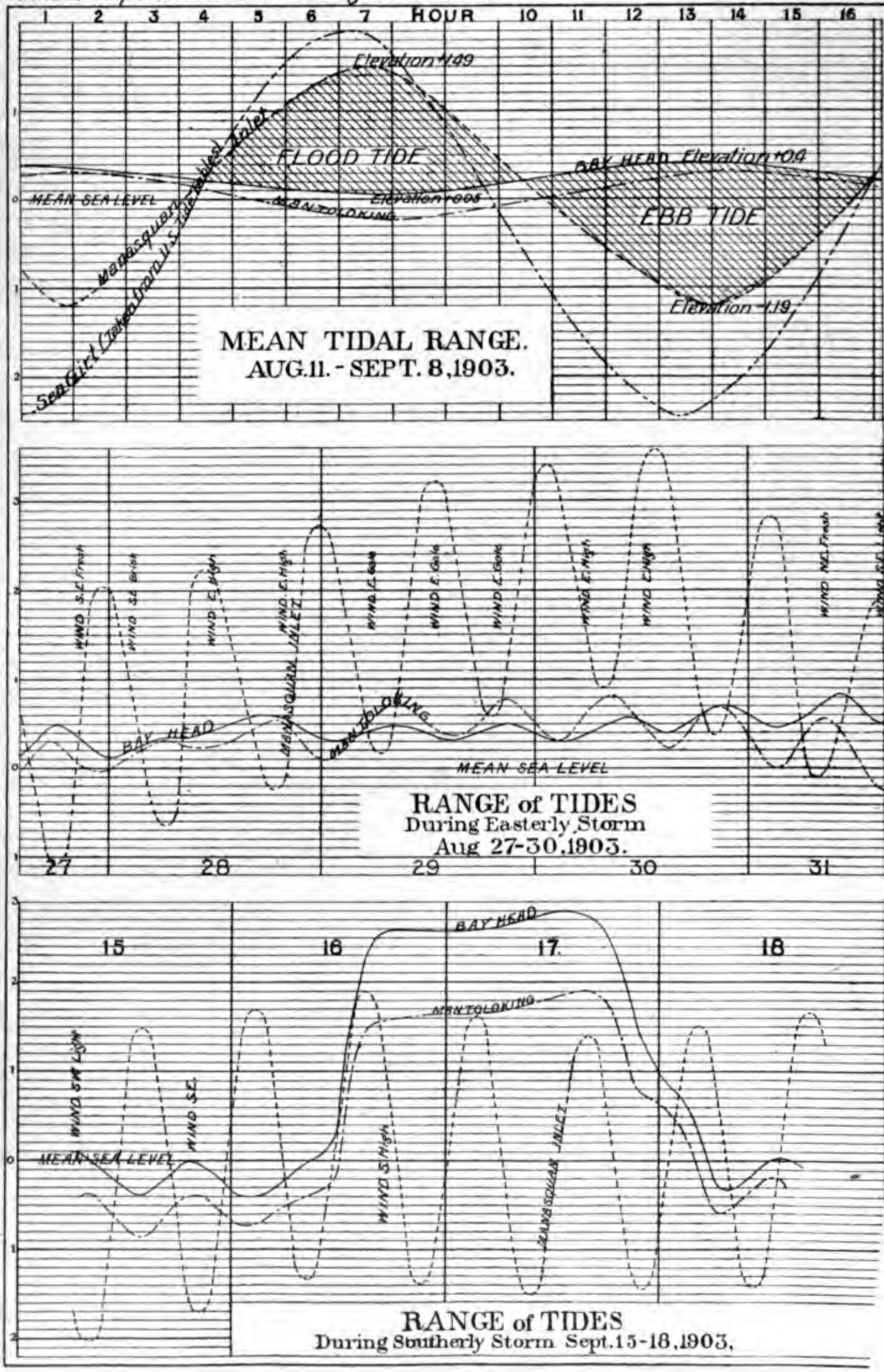
2. This act shall take effect immediately.

Approved April 7, 1903.

The Board of Managers of the Survey, at a meeting held April 28th, 1903, authorized the State Geologist to engage as engineer Mr. C. C. Vermeule, of East Orange, to make the necessary surveys, and directed that the work be done under the direction of the State Geologist and Executive Committee of the Board. On July 31st, the Committee of the Board, Mr. Vermeule and the State Geologist visited Point Pleasant and in company with a local committee examined the site of the proposed waterway. Detailed surveys and tidal observations were carried on under Mr. Vermeule's direction during the following weeks, after which the accompanying report was prepared by him and submitted to the Board of Managers of the Geological Survey at their Annual Meeting, December 22d.

In accordance with the above statute, it has been transmitted to the Governor, and is herewith submitted to the Legislature.

HENRY B. KÜMMEL,
State Geologist.



HOUR
1 2 3 4 5 6 7 10 11 12 13 14 15 16
Elevation +1.49
FLOOD TIDE
BAY HEAD Elevation +0.4
MEAN SEA LEVEL
MANTOLOKING
Elevation +0.05
EBB TIDE
Elevation -1.19
Manasquan Inlet
Sea Girt (taken from U.S. Tide Tables)
MEAN TIDAL RANGE.
AUG.11.-SEPT. 8,1903.
WIND S.E. Fresh
WIND S.E. Brisk
WIND E. High
WIND E. High
MANASQUAN INLET
WIND E. Gale
WIND E. Gale
WIND E. Gale
WIND E. High
WIND E. High
WIND NE. Fresh
BAY HEAD
MANTOLOKING
MEAN SEA LEVEL
RANGE of TIDES
During Easterly Storm
Aug 27-30,1903.
27 28 29 30 31
15 16 17. 18
BAY HEAD
MANTOLOKING
WIND SW Light
WIND SE.
MEAN SEA LEVEL
WIND S. High
MANASQUAN INLET
RANGE of TIDES
During Southerly Storm Sept.15-18,1903.

Report on a Proposed Tide Waterway Between Bay Head and Manasquan Inlet.

In accordance with instructions, and by authority of the Act of the Legislature approved April 7th, 1903, I have made a survey and estimates of the proposed tide waterway connecting Manasquan Inlet with Barnegat Bay, at Bay Head. An examination of the proposed route was made in company with a committee of the Board of Managers and the State Geologist, on the 31st day of July last. A few days previous surveys had been begun, and the entire route of the canal was surveyed from Manasquan Inlet to Bay Head. Tidal observations were also made at Manasquan Inlet, Bay Head and Mantoloking. The results of the surveys and examinations are shown, together with the proposed route of the canal, on the general plan accompanying this report.

The first matter which required careful consideration was the relative height of tides in Barnegat Bay and in Manasquan Inlet. Something was already known as to this from the results of the topographic survey, but more definite information was obtained by means of the tide gauges established this summer. The results of the gaugings are shown in Plate I.

The first diagram, entitled "Mean Tidal Range," gives average conditions during a single tide at the several points, and also at Sea Girt, the curve for which place represents the tides in the ocean during the period under consideration. The period taken, from August 11th to September 8th, fairly represents average conditions, and the tides shown in the diagram may be considered to be typical. It should be observed that high tide just within Manasquan Inlet is a little later than in the ocean, and is 0.4 of a foot lower; while low tide is about 40 minutes later within the inlet, and 1.25 feet higher than low tide in the ocean, the range

within the inlet being, therefore, 1.65 feet less than in the ocean, during the same period.

The observations at Bay Head and Mantoloking indicate the conditions at the head of Barnegat Bay during the same period. It will be seen that at both of these places low tide is nearly coincident with high tide in the ocean outside. It will also be noted that the range of tide is quite small in the bay, being less than 0.4 of a foot at Bay Head, and about 0.55 feet at Mantoloking. The diagram shows that at high tide in Manasquan Inlet the water at the head of Barnegat Bay is 1.44 feet lower than at Manasquan Inlet, and that at the time of low tide at Manasquan Inlet the water in the bay is 1.59 feet higher. Supposing a canal to be cut connecting the two, the shaded portion, lettered "Flood Tide," in the diagram represents the time during which the water would flow from the Inlet into Barnegat Bay, and the shaded portion, marked "Ebb Tide," shows the time during which the water would flow from the bay toward Manasquan Inlet, the two shaded portions representing one complete cycle of tides, and illustrating, as we have said before, average conditions.

The second diagram in the plate, entitled "Range of Tides during Easterly Storm, August 27–30, 1903," shows the relative height of the tides at Manasquan Inlet, Mantoloking, and Bay Head. It will be observed that the water during this storm was generally much higher at the Inlet than it was in Barnegat Bay. On August 30th, the ocean was about 1.7 feet higher on the average than the bay, and high water at Manasquan Inlet was 3.1 feet higher than the water at Bay Head in the bay. This is due to the fact that since the general direction from the head of the bay to Barnegat Inlet is southwesterly, the effect of an easterly storm is to drive the water out of the bay toward the inlet, causing low water at the head of the bay; whereas in the ocean the tendency is to pile up the tides higher than usual.

The third diagram, entitled "Range of Tides during Southerly Storm," shows contrary conditions to the previous one. The effect of a southerly storm is to pile up the water at the head of Barnegat Bay to an unusual height. It will be observed that during low water at Manasquan Inlet, on the 17th of September, the water at Bay Head was 4.3 feet higher than it was at Manas-

quan Inlet, and that even during high tide at Manasquan Inlet the water at no time reached so high a point as the level of the bay at Bay Head or Mantoloking.

These three diagrams show about the range of conditions which we would have to contend with when the proposed canal is constructed. That is, for ordinary working conditions we should have a fall, during high water at Manasquan Inlet, of 1.44 feet toward Barnegat Bay, and during the time of low water in Manasquan Inlet we should have a fall of 1.59 feet from the bay toward the inlet, and the variation of fall in either direction is shown by the first diagram in the plate. But during an easterly storm, such as that shown in the second diagram, the water would flow from the inlet into Barnegat Bay almost without cessation, during a period of two days or more; while during a southerly storm the water would flow continuously from Barnegat Bay toward Manasquan Inlet, during a period covered by two or three tides; and the canal must be so designed that the maximum fall during such a period of storm will not cause so high a velocity of water as to wash away the banks of the canal.

Considering further conditions in Barnegat Bay, which it is sought to remedy by the construction of the proposed tide waterway, we find that, while the average range of tide in the ocean, or the difference between average low tide and average high tide, amounts to 4.7 feet, the range just inside of the inlet, in Barnegat Bay, is only 2.04 feet, and at Seaside Park it is reduced to 0.88 feet, at Kettle Creek to 0.47 feet, and, as shown by our diagram, at Mantoloking to 0.55 feet, and at Bay Head to 0.35 feet. The distance from Barnegat Inlet to Bay Head is about twenty-one miles. Although there is a great rush of water into and out of Barnegat Inlet at each tide, there is not time during a single high tide to fill up the bay inside, nor is there time for the water in the bay to run out at low tide. There was formerly an inlet known as Cranberry Inlet, between Seaside Park and Ortley. This inlet is shown as closed in a map dated 1850. It is also stated that there was another inlet opposite the mouth of the Metedeconk River, which inlet closed some time about 1755. There are evidences that at a still earlier date the Metedeconk River found its

way out northward to Manasquan Inlet, along a line now proposed for the tide waterway.

The effect of the closing up of the old inlets has been to constantly decrease the saltness of the water at the head of Barnegat Bay, and to greatly limit the area adapted for oyster culture. In order to determine the difference in salinity of the water at points where the oyster now thrives, and at points near the head of the bay where there are at present no oysters, four samples of water were taken and submitted to Dr. Thomas B. Stillman, of Stevens Institute, for analysis. The results of the analyses are given herewith:

STEVENS INSTITUTE OF TECHNOLOOGY,
HOBOKEN, N. J., August 22d, 1903.

Cornelius C. Vermeule, C. E., 203 Broadway, New York City:

DEAR SIR—The four samples of water, received from you August 16th, have been subjected to a partial chemical analysis, with the following results (figures represent grains per U. S. gallon):

	Total Solids.	*Organic and Volatile Matter.*	*Sodium Chloride.*
No. 1, marked Seaside Park, Barnegat Bay,..	522.21	108.56	403.71
No, 2, Bay Head, Barnegat Bay, ...	16.79	4.19	12.80
No. 3, Manasquan Inlet, ...	1851.52	181.86	1533.61
No. 4, Mantoloking, Barnegat Bay, ...	3.96	2.30	1.90

Respectfully yours,
(Signed) THOS. B. STILLMAN.

Sample No. 3 of the above was taken at Manasquan Inlet, and represents practically pure sea water. Sample No. 1 was taken about one mile below the railroad bridge, at Seaside Park, and at a point where oysters are raised successfully. No. 2, at Bay Head, and No. 4, at Mantoloking, represent conditions at the head of the bay and are practically equivalent to fresh water. It will be observed that the sodium chloride in sample No. 1 is only a little more than one-fourth as much as in sample No. 3, and yet, as we have said, this water appears to be well adapted to raising oysters; so that it would appear that 30 per cent. of its volume in sea water would be sufficient to add to the water at the head of Barnegat Bay, in order to make it suitable for oyster raising.

The fresh water inflow to the head of Barnegat Bay, including all the streams entering above Toms River, I estimate amounts to an average of 134,000,000 gallons daily, so that if we could add to the bay 30 per cent. of this amount, or 40,000,000 gallons each day of pure sea water, we should have the proper proportions for oyster culture. It would be easy to add this proportion of sea water if the flow of the canal were always in one direction; but inasmuch as the flow is half of the time from the bay toward the ocean, as shown by the diagrams of the tides, the average capacity of the canal during the incoming tide would have to be at least double the above amount, or 40,000,000 gallons in twelve hours.

ROUTE OF THE CANAL.

Consideration was given to two possible routes for the proposed tide waterway. One of these is about 1½ miles west of the New York and Long Branch Railroad, starting from a point 2½ miles up the Manasquan River, from the inlet, and running in a direct line to Metedeconk River. This route was examined, but it involves heavy cutting, and the first cost will be greater than on the route chosen because of the large amount of earth to be handled. Furthermore, the effectiveness of a canal at this point is doubtful, because it starts so far up the Manasquan River that the water would be much less salt than if taken near the inlet. Finally, considering its merits as a navigable waterway, it would be very much inferior to the route selected because of the shallowness of the Manasquan River between the proposed route of the canal and the inlet.

The route finally selected is shown in detail on the accompanying map, Plate II. It passes through a chain of small ponds and a line of marshes, the ground along the route being very low, the highest ground met with being 4.7 feet above mean tide, while much of the way it is actually below mean sea level. The proposed route begins a little north of the present railroad bridge over the outlet of Twilight Lake at Bay Head, and follows up said outlet and through Twilight Lake. Thence crossing Osborn avenue and Sea avenue, it skirts the easterly edge of Maxon's

Pond. after which it follows the line of Baltimore avenue through Point Pleasant.

In order to get proper room for the canal and for a roadway each side, it will be necessary to acquire a row of lots 50 feet wide at the easterly side of Baltimore avenue. This will give room not only for the canal with a width of 60 feet, but for a roadway on each bank 17 feet wide, and an 8-foot sidewalk, as shown in section on the plan. This necessitates the removal of one house, this being the only structure interfered with along the entire route. After reaching Central avenue, the canal curves eastward through Cook's Pond, and follows the outlet of Cook's Pond to Manasquan Inlet. It will be observed that this route is quite direct, while at the same time it follows existing water courses and cuts through the several seaside resorts in such a manner as to do the least possible injury to property. The section adopted for the canal, in order to meet all requirements, viz., to pass a sufficient amount of salt water into Barnegat Bay to adapt the head of the bay to the culture of oysters, and also to render the canal as valuable as possible for a navigable waterway, has a width of 60 feet at mean tide level, with side slopes of one perpendicular to two base, and a depth of 10 feet, giving a bottom width of 20 feet. Through Baltimore avenue, both banks of the canal would be bulkheaded with low bulkheads, as shown in the section.

The several ponds met with, viz., Cook's Pond, Little Silver Lake, Maxon's Pond and Twilight Lake, or some of them, if allowed to constantly empty and refill with each tide, would absorb a large part of the capacity of the canal and diminish the amount of water which would reach through the canal into Barnegat Bay; consequently some of these are cut off by side embankments, as shown in the section, through Twilight Lake, these embankments being formed of material dredged from the canal. Cook's Pond is allowed to ebb and flow at each tide, the canal from that point to the inlet being increased in width to 80 feet, in order to admit of this. Little Silver Lake has an ordinary water elevation of 1.2 feet above mean tide, while the elevation of the bottom is shown by the figures on the plan to be generally slightly below mean tide, and the deepest is but two feet below. If the tide were allowed to ebb and flow in this lake its bottom would be largely

bare at low water, consequently it is embanked off from the canal; and waste-weirs should be provided at about high-tide level over which any excess of water in the lake may flow into the canal.

The ordinary elevation of Maxon's Pond is 3.1 feet above mean tide, which is about 2 feet higher than high tide in the canal, as shown by the profile. This pond could be either banked off like the others, or could be almost entirely drained off through the canal by means of tide sluices, which would allow the water to flow out at low tide, but would not allow any water to flow from the canal into the pond. Twilight Lake has a considerable depth and quite a large area, and I have planned to embank this off in the manner shown in the section providing a waste-weir over which the surplus waters can flow into the canal when the lake fills to mean high tide. The portion of this lake lying between the canal and Lake avenue is about 150 feet wide, and could perhaps be very advantageously filled in the future and used for building purposes.

Eight highway bridges would be required across the canal, and one railroad bridge. If the canal should be used as a navigable waterway, for which purpose it would probably be largely in demand, these bridges should be draw-bridges. They could properly be bascule bridges, of about 30 feet clear span, and I have estimated upon bridges of this character.

If constructed of these dimensions and on these general lines, the cost of the proposed tidal waterway would be as follows:

Excavation, 727,411 cubic yards, at 15 cents,	$109,111 00
Bulkhead, 3,860 feet, at $1.80,	6,948 00
Eight highway bridges,	19,200 00
One railway bridge,	5,250 00
Total,	$140,509 00
Incidentals, engineering, contingencies,	14,051 00
	$154,560 00

The exact effect of such a tide waterway as above designed can be best ascertained by following the sequence of events through a single tide. We are able to compute accurately the amount of water passing from the data furnished by the surveys. At the

beginning, the inflow during an average flood tide lasting 6 hours will be 88,500,000 gallons, while the average outflow during an ebb tide lasting 6½ hours will be 93,500,000 gallons. Of course, the excess of outflow cannot be kept up without slightly affecting the level of the bay, but we find by computation that when the bay has fallen 0.1 foot the inflow and outflow will be equalized, and will amount to 91,000,000 of inflow and the same amount of outflow during each tide. It is impossible for the canal to affect the level of Barnegat Bay more than 0.1 foot therefore, which is practically inappreciable.

When the flow has been equalized we must bear in mind that the outflow from the bay will fill the entire prism of the canal with water of the same character as the bay water, which will be mixed with sea water as soon as the canal begins to operate. Consequently, while the inflow into the canal from Manasquan Inlet will be 91,000,000 gallons for each tide, all of this will not reach the bay, but the quantity contained in the prism of the canal, amounting to 48,000,000 gallons, will have to be first pushed back into Barnegat Bay. This will leave 43,000,000 gallons net inflow of sea water into the bay, at Bay Head, during each flood tide, and to this must be added the proportion of sea water which is contained in the canal prism, which will be the same proportion, practically, as in Barnegat Bay.

At the beginning, therefore, when very little salt water has been introduced into the bay, there will be 43,000,000 gallons net inflow of sea water, while there will be practically no outflow of salt water, and consequently each tide will deposit upwards of 40,000,000 gallons of salt water in the bay. This will rapidly increase the saltness of Barnegat Bay at first, and the saltness later on will increase more and more slowly during the operation of the canal. We have already seen that the proportion should be at least 30 per cent. of sea water to make possible the cultivation of oysters. Let us estimate, therefore, the conditions of inflow and outflow when the bay water has become 30 per cent. salt.

During the flood tide, the inflow into the bay will be, from the canal prism, 48,000,000 gallons, which contains 30 per cent. of sea water, making 14,400,000 gallons of sea water from the canal;

and to this must be added 43,000,000 gallons additional of pure sea water, making the total amount of sea water added, 57,400,000 gallons. For the same conditions, the outflow on the ebb tide will be 91,000,000 gallons of bay water, which contains 30 per cent. of sea water, amounting to 27,300,000 gallons. There will, therefore, be left in the bay, during each tide, the difference between 57,400,000 gallons and 27,300,000 gallons, or 30,100,000 gallons of salt water. As there are not quite two full tides in 24 hours, the net addition of salt water to the bay during 24 hours will be 58,000,000 gallons. We have previously seen, however, that the inflow of fresh water from the upland streams into the bay averages 134,000,000 gallons in 24 hours, and that in order to maintain the bay at 30 per cent. sea water we need to add only 40,000,000 gallons of sea water each 24 hours. This is considerably less than what is actually added according to the above estimate; consequently the saltness of the bay will go on increasing beyond the estimated 30 per cent.

A similar computation shows that when the bay has had added to it 40 per cent. of sea water, the canal will still be adding slightly to the saltness, so that by this system of computation Barnegat Bay will be maintained in a condition averaging a little more than 40 per cent. of sea water, the saltness increasing somewhat beyond this when the upland streams are low, and decreasing somewhat below it during wet weather.

A canal of the size which we have planned, therefore, will maintain the water of Barnegat Bay in a sufficiently salt condition to make possible the cultivation of oysters, and will do this leaving a margin of safety of over 30 per cent. in our estimates.

The section of the canal could be diminished to a top width of 40 feet, and the total cost could be thereby reduced to $105,000; but the efficiency would thereby be very considerably diminished, and the capacity of the canal would not be sufficient to make all of the head of the bay available for oyster culture, although it would render a considerable part of it sufficiently salt for this purpose.

The area of that portion of Barnegat Bay north of Toms River, which would, through the operation of this canal, be made available for culture of oysters, covers 9,000 acres in all.

A further important advantage of such a waterway will be as an aid to navigation through our inland waters, particularly in connection with the development of our sea-coast summer resorts. These summer resorts have assumed an importance to this State which makes them equally worthy of consideration with the oyster industry. Many of the New England States recognize the advanages of catering to the increasing number of persons who seek an outing by the seaside and elsewhere during the summer; and there is no reason why the State of New Jersey should not do likewise. Either yachts, oyster boats, or other craft desiring to reach the head of Barnegat Bay from the north, must now pass south to Barnegat Inlet, and thence northward to the head of the bay. The distance from Manasquan Inlet to Bay Head, by this route, is 46 miles, whereas by the proposed canal it would be reduced to 3 miles. What is true as to craft desiring to reach Bay Head, is true to only a slightly less degree of those wishing to reach other points on Barnegat Bay, such as Mantoloking, Silverton, Seaside Park, Island Heights, Toms River, etc.

The importance of the canal as a navigable waterway would be still further enhanced if the Federal Government should continue its policy of improving Manasquan Inlet. Jetties were built there some years ago, but the design adopted has proven to be not well adapted to the locality, and the southern jetty has been undermined and almost disappeared. The northern one, however, stands in good condition but needs to be extended, and if extended, there appears to be no good reason why a depth of 10 feet should not be maintained through the inlet. It is doubtful if the southerly jetty is needed at all. It seems probable that this improvement will be continued, and in that case the canal will admit of vessels of 9 feet draft passing through into Manasquan Inlet, and thence to Bay Head.

The canal would be a further advantage as a means of draining the low-lying section through which it passes, and its advantages in this respect would probably be sufficient to induce the property owners along the line to grant a free right of way, consequently I have added nothing to my estimate for the cost of right of way.

The surveys and examinations made are sufficient to enable me to report definitely that such a tide waterway is practicable, and will be effective as a benefit to the oyster industry as well as in other directions which I have pointed out.

Respectfully submitted,

C. C. VERMEULE,

Consulting Engineer.

PART II.

The Floods of October, 1903.—Passaic Floods and Their Control.

By C. C. VERMEULE.

Passaic Floods and Their Control.

BY C. C. VERMEULE.

This Survey has kept a record of all the important floods on the Passaic river during the last twenty-seven years, and has obtained data of earlier floods so far as possible. Although the Passaic is by no means a violent stream during floods, when measured by its maximum discharge per square mile of watershed, nevertheless it has long been apparent that the steady increase of the valuable property upon the lower reaches of the stream, and the gradual encroachment upon its channel, would be likely to call for some regulation of the flood-flows. Inasmuch as any regulation of the flow would call for a thorough understanding of the movement of floods in the valley above Little Falls, special attention has been given to this phase of the subject in previous reports of the Survey. In the Report on Water-Supply of 1894 we gave a list of all the floods of seventeen years previous to that date, and a full analysis of the flood of 1882, which at that time was the highest flood of which we had complete records. Again, in the Annual Report for 1896 we gave full data and an analysis of the flood of that year, which, although it was comparatively a harmless flood on the lower part of the stream, was rather violent on some of the branches, and had features which rendered it peculiarly instructive. In the report for 1902 we gave a full analysis of the great flood of that spring and the effect of the proposed drainage works above Little Falls upon the flood-flows. In that report we also called attention to the possibilities of controlling floods by means of a large storage reservoir. Furthermore, the report of 1902 gave the more important data included in a special report upon the drainage works above Little Falls,

which had been made to a Committee of the Board of Managers of this Survey in 1893-4.

It has long been apparent to us that any effectual control of the floods of the river must be exercised at or above Little Falls. The present report, dealing with the flood of last October, is in continuation of the previous studies of these floods, and contains more explicit information as to proposed methods of control.

FLOOD OF OCTOBER, 1903.

For the second time since the writing of the Report on Water-Supply in 1894, we are called upon to record a flood on the Passaic exceeding the great flood of September, 1882. In October, 1903, floods occurred on the Passaic which exceeded in height and volume any previous floods of which we have record. In last year's report it was stated that the flood of March, 1902, exceeded all since 1810. The flood of October, 1903, exceeded the flood of 1810. The rainfall was particularly heavy in the extreme northern part of the State, but much lighter on the more southerly streams, so that previous flood records were not broken on any other streams than the Passaic and the Delaware.

Cause.—There is a growing impression in the public mind that the increased violence of floods is due to some artificial changes in the streams or on their watersheds; but if we direct our attention to the meteorological conditions and compare them with previous conditions, we find that they are ample to account for the particular violence of the floods of last October. The average precipitation at eleven stations, distributed over the Passaic catchment in such a manner as to indicate accurately the average precipitation on the catchment, shows the rainfall to have been as follows:

On the 8th of October, including a light rain which fell on the 7th, the rainfall was 2.21 inches; on the 9th it was 7.83 inches; on the 10th, 1.55 inch, and on the 11th, 0.39 inch, making a total for four days of 11.98 inches on the Passaic watershed. The rainfall at the several stations varied from 9.74 inches, at Hanover, to 15.61 inches, at Paterson. It was 13.39 inches at

Little Falls, and 13.50 inches at Pompton Lakes, the heaviest precipitation having occurred on the Pompton river and its tributaries, the Ramapo, Wanaque and Pequannock.

Comparison with previous rainfall.—It becomes interesting to compare the daily rainfall during the four high floods of the present century, in order to show the importance of the relative concentration of the rainfall, which is one of the important factors causing extreme floods. The following table furnishes the data of daily rainfall for these floods. In it I have taken the rainfall for 1882 from the best records obtainable to exhibit the average rainfall on the Passaic catchment, although the record for that year is not as satisfactory as for the more recent floods. A comparison with the several stations of which data are available leads me to believe that the figures here given are, however, reasonably accurate for 1882.

TABLE I.

DAILY RAINFALL—INCHES.

Flood of 1882.		*Flood of 1903.*	
Sept. 20,	0.73	Oct. 8,	2.21
21,	0.73	9,	7.83
22,	4.70	10,	1.55
23,	7.40	11,	0.39
Total,	13.56	Total,	11.98

Flood of 1896.		*Flood of 1902.*	
Feb. 6 and 7,	4.37	Melting snow,	2.65
Includes rain and melting snow.		Feb. 28,	1.61
		Mar. 2,	0.91
		5,	1.05
Total,	4.37	Total,	6.22

The floods of 1882 and 1903, both being autumn floods, may be properly compared, while those of 1896 and 1902, being winter floods, are also comparable. It will be observed that, although the flood of 1903 was much greater than that of 1882, the total rainfall was less, and it was less concentrated. We must, therefore, look to some other cause than the volume of rainfall and its concentration for this difference. The primary cause of the great

flood of last October will be found to be that the heavy rainfall occurred at a time when the streams were already full and the ground was filled with water. Our previous reports have called attention to the fact that in 1882 the ground was very dry, and a large part of the rainfall was absorbed by percolation. The difference in the rainfall conditions preceding the two floods is well exhibited in the following table of precipitation:

TABLE II.

RAINFALL CONDITIONS PRECEDING AND DURING THE FLOODS OF SEPTEMBER 25, 1882, AND OCTOBER 10, 1903.

Inches of Rainfall.

	1882			1903		
	July.	*Aug.*	*Sept.*	*Aug.*	*Sept.*	*Oct.*
Paterson,	7.02	2.37	25.98	10.98	2.88	16.19
Newark,	3.52	1.31	17.66	14.54	4.56	13.26
South Orange,	3.61	1.35	14.45	13.57	3.80	11.46
Elizabeth,	4.32	2.49	18.58	7.15	3.88	10.25
New Brunswick,	3.04	3.20	15.52	6.52	3.23	7.76
Average,	4.30	2.14	18.44	10.55	3.67	11.78

It will be observed that in 1882 there had been a light rainfall in July and August. Indeed, there had been a protracted deficiency of rainfall during several months, and this continued down to the 19th of September, when the heavy rain began, whereas in 1903 the summer had been wet.

The different conditions existing during the several floods brought about results which are well exhibited in the following table, the figures therein given for 1882 being re-computed for this report from data which probably fairly represent actual conditions on the Passaic catchment:

TABLE III.

	Rainfall, inches.	*Run-off, inches.*	*Per cent. of Rain.*	*Computed Evaporation, inches.*	*Percolation or Loss, inches.*
September, 1882,	13.56	3.71	27.4	3.14	6.71
February, 1896,	4.37	3.18	73.0	0.53	0.66
March, 1902,	6.47	5.35	82.7	0.77	0.35
October, 1903,	11.98	7.12	59.3	1.73	3.13

In this table the rainfall is that to which the flood is immediately due in each case, and the run-off gives the volume of water discharged by the Passaic during the flood, which lasted eight days for the first three floods given, and eleven days during October of the present year. The run-off is given in inches on the catchment, and also as the percentage of rainfall. The percentage of rain flowing off will be seen to vary through wide limits, being greatest in March, 1902, and least in September, 1882. The next column, showing "Computed Evaporation," gives the amount of water evaporated during the eight to eleven days of flood, this quantity being computed by the monthly formulæ given on page 80 of the Report on Water-Supply. Adding together the computed evaporation and the run-off, and subtracting the sum from the rainfall, we have left the percolation, or water otherwise unaccounted for, as shown in the last column. This will be seen to vary considerably according to the condition of the ground at the beginning of the rain. The above computation of percolation for 1882 agrees very well with an entirely independent method of computation given on page 215 of the Report on Water-Supply.

Table III, as I have said, exhibits clearly what occurred during each of the floods on the Passaic, and explains why a larger amount of rain in September, 1882, produced a smaller flood than a less amount of rain in October, 1903, the cause being simply the greater ability of the ground to absorb water at the end of the protracted drought of 1882. The table also inevitably presents to the mind the question of what might occur if such a rain as that of September, 1882, or that of October, 1903, should come with the ground as fully saturated as it was in March, 1902, when it absorbed almost no water. Under those conditions, instead of the 7.12 inches of run-off from the catchment, which we had during October last, we should have had from 11.63 to 13.21 inches of run-off. It cannot be said that such a coincidence is impossible, any more than we could say after the flood of 1882 that such heavy rainfall could not come on ground nearly saturated, which actually happened last October.

The flood which resulted from the rainfall of last October is shown graphically in the diagram, Plate III, being compared with

similar diagrams for the other three great floods. The diagram makes the great violence of this flood apparent to the eye. The suddenness of the rise is marked, as compared with the flood of 1902, and in this respect the flood of the present year agrees generally with the other two floods shown in the diagram. The relative volume, as well as the relative maximum discharge, is also shown by the diagram, and is further exhibited in the following table:

TABLE IV.

GREAT FLOODS ON THE PASSAIC AT DUNDEE SINCE 1876. AREA OF WATERSHED, 822.7 SQUARE MILES.

Date of Maximum Discharge.	Greatest Discharge, Cubic Feet, per Second.	Time from Beginning of Rise to— Maximum Hours.	Time from Beginning of Rise to— End, Days.	Total Discharge— In Million Cubic Feet.	Total Discharge— Inches on Watershed.
October 10, 1903,....	31,410	50	11	13,619	7.12
March 2, 1902,.......	22,677	91	8	10,219	5.35
September 25, 1882,..	18,265	66	8	7,101	3.71
February 8, 1896,....	17,217	44	8	6,083	3.18
December 12, 1878,..	16,592	60	8	6,878	3.47
February 14, 1886,...	12,452	60	8	5,729	3.00

The only other extreme floods of which we have any record are those of 1810 and 1865. From flood marks up the valley above Little Falls I estimate that the flood of 1810 had a maximum discharge of 25,500 cubic feet per second, while that of 1865 was nearly as high as the flood of 1902. Table IV makes plain the fact that the flood of October 10th of the present year was a very unusual one, both in its maximum discharge and in the total volume of run-off. The time from the beginning of the rise to the maximum, being only fifty hours, is also very short for so great a flood.

History of the October flood.—Ae we have already pointed out, Plate III shows the comparative rapidity of rise and volume of the four great floods of which we have a reliable record. The history of the flood of last October is exhibited in Plate IV. The beginning of the sudden rise was almost simultaneous on all branches, being at about 6 P. M. on Thursday, October 8th. The

main stream reached its maximum at Little Falls at 2 P. M. of the 10th, and at Dundee at about 8 P. M., the difference being, as usual, six hours.

The maximum at Two Bridges was between Saturday noon and 2 P. M. The Pompton, however, reached a maximum at 4:30 P. M. of the 9th (Friday), at which time a fairly close estimate of the discharge past the Morris Canal aqueduct at Mountain View gives 23,407 cubic feet per second. At the same hour the flow over the dam at Dundee amounted to only 17,000 cubic feet per second, and the recorded heights at Little Falls show that it was still less there. This phenomenon is explained by the fact that part of the waters of the Pompton were at that time flowing past Two Bridges up-stream into Great Piece meadow. This is represented graphically in Plate IV by a negative discharge of the southerly branches at Two Bridges. This is a peculiar phenomenon to which we have frequently called attention heretofore, especially in the report of 1902.

The Pompton has a catchment of only 380 square miles, while the main Passaic at Little Falls has a catchment of 773 square miles; yet at a certain time during the rising flood the Pompton branch shows a materially greater discharge than the main stream. This is due to the more precipitous topography of the Pompton catchment, and to the fact that the southerly branches spread their waters over the large area of flat lands comprised in Great Piece meadow, Hatfield swamp and the Troy and Black meadows.

The main channel below Two Bridges, to Little Falls, is somewhat restricted, as is shown by the several cross-sections in the report of 1902. Before this channel can discharge a quantity as great as the Pompton maximum, Great Piece meadow above Two Bridges must be filled up to the necessary height.

After 4:30 P. M. of the 9th the Pompton continued a high rate of discharge until noon of the 10th, after which it steadily fell off. Plate IV shows graphically the time of the maximum on the Wanaque, Ramapo and Rockaway. The Whippany reached a maximum at 5 P. M. of the 9th, and the upper Passaic at Chatham was at its highest about midnight of the 9th. From the beginning of the rise, therefore, the Wanaque, Ramapo, Pe-

quannock and Whippany reached a maximum in from 18 to 23 hours, and the average may be taken at 20 hours. The Rockaway and upper Passaic required from 30 to 33 hours, while the Pompton at Mountain View reached a maximum in about 22 hours, the Passaic at Little Falls in 44 hours, and the Passaic at Dundee in 50 hours.

Plate V (in pocket) is a map showing the area of the submerged lands during the October flood. The area tinted blue represents the land covered at the maximum height of the flood, although this maximum did not occur at all points at the same time.

Plate VI shows in profile the movement of the flood on the Passaic and its branches above Little Falls. Beginning with the bank-full stage, which was reached on the evening of the 8th instant, the water rose steadily until at 5 P. M. on the 9th, or Friday, it had reached a maximum on the Pompton at Mountain View, and also on the Whippany at Whippany. The profile shows the stage of the water along the river at this time. It will be seen that the slope was rapid down through the Troy meadows and the other branches into the Great Piece meadows, but that it was higher at Two Bridges than in the meadows, as at this time the water was flowing backward from the Pompton and filling up the Great Piece. At 7 P. M. the Great Piece had been filled up, and at this time the discharge of the Pompton and of the main Passaic at Little Falls were about equal.

From this time the water began to flow downward from Great Piece meadow, past Two Bridges, although it continued to rise at all points from Little Falls to Cook's bridge on the main stream until Saturday noon. It was, however, at the same time falling on the Black meadows and the upper part of the Troy meadows, and also on the Pompton. At the maximum on Saturday noon the river was nearly 12 feet above bank-full stage at Two Bridges, and 8 feet above at Pine Brook, Swinefield bridge and Cook's bridge. I estimate the volume of water on these flats to have been very close to 6,000,000,000 cubic feet at the time of the maximum accumulation, at noon of October 10th. After this time it steadily subsided. Up to 2 P. M. of the 10th the discharge past Little Falls had aggregated about 2,500,000,000 cubic feet. Adding the 6,000,000,000 cubic feet accumulated on

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the flats, we have 8,500,000,000 cubic feet discharged by the several branches into the flats during these 44 hours. Following this time to the end of the flood, the branches discharged about 5,000,000,000 cubic feet additional.

The Ramapo at about 5:40 A. M. of October 9th, when the Pompton Steel Works dam broke, had reached a discharge of 7,123 cubic feet per second. The Wanaque about noon of Friday reached a discharge at Pompton Lakes of 8,445 cubic feet per second, and the Rockaway at the head of Boonton falls reached a discharge of 5,764 cubic feet per second Saturday at 4 A. M. Table V shows the maximum rates of discharge and the relative suddenness of the rise for the four great floods under consideration.

TABLE V.

MAXIMUM RATES OF DISCHARGE ON THE PASSAIC AND ITS BRANCHES.

	Catchment, square miles.	September 22, 1882.		February 6, 1896.		March 2, 1902.		October 10, 1903.	
		Hours, beginning to maximum.	Greatest discharge, cubic feet per second.	Hours, beginning to maximum.	Greatest discharge, cubic feet per second.	Hours, beginning to maximum.	Greatest discharge, cubic feet per second.	Hours, beginning to maximum.	Greatest discharge, cubic feet per second.
Passaic at Dundee,.........	822	65	18,265	44	17,217	91	22,677	50	31,410
Passaic at Little Falls,......	773	66	19,000	44	16,745	81	21,207	44	......
Pompton at Two Bridges,a.	380	30	16,000	13	18,500	54	17,900	22	23,407
Ramapo at Pompton,.......	160	24	10,540	24	8,731	54	7,049	12	7,123 b
Wanaque at Pompton,......	101	24	6,666	11	7,203	54	6,187	18	8,445
Pequannock at Pompton,...	85	20	4,460	7	5,500	50	4,600	...	......
Rockaway at Boonton,......	118	36	4,800	16	5,445	51	4,540	32	5,764
Whippany at Whippany,....	38	...	......	10	3,200	47	2,600	...	......

Note.—*a.* Pompton river discharge is approximate only.
b. Dam went out—actual maximum probably near 9,000.

Referring to Plate VII, which shows the profile of the river from Two Bridges to Beattie's dam, it will be noted that the flood of 1903 was proportionately higher at Beattie's dam than at other points up stream. It, therefore, seems doubtful if any detailed

computation of the discharge over Beattie's dam for the present flood is reliable, and I have not attempted to make such computation. Table V shows that not only the Passaic, but its several branches, reached a higher point than ever before during the flood of last October. The Ramapo river has been gauged heretofore at Pompton dam, but this structure went out when the discharge had reached a little over 7,000 cubic feet per second. Undoubtedly the maximum discharge was much in excess of this.

Plate VII, showing the height of the several floods from Beattie's dam to Two Bridges, brings out the fact that the difference between this and the flood of 1902 was greater at Deepavaal and Two Bridges than at points near Singac, and thereby indicates what we have previously pointed out; *i. e.*, that this part of the river channel from Two Bridges to Beattie's dam, rather than the dam itself, really controls the discharge of floods.

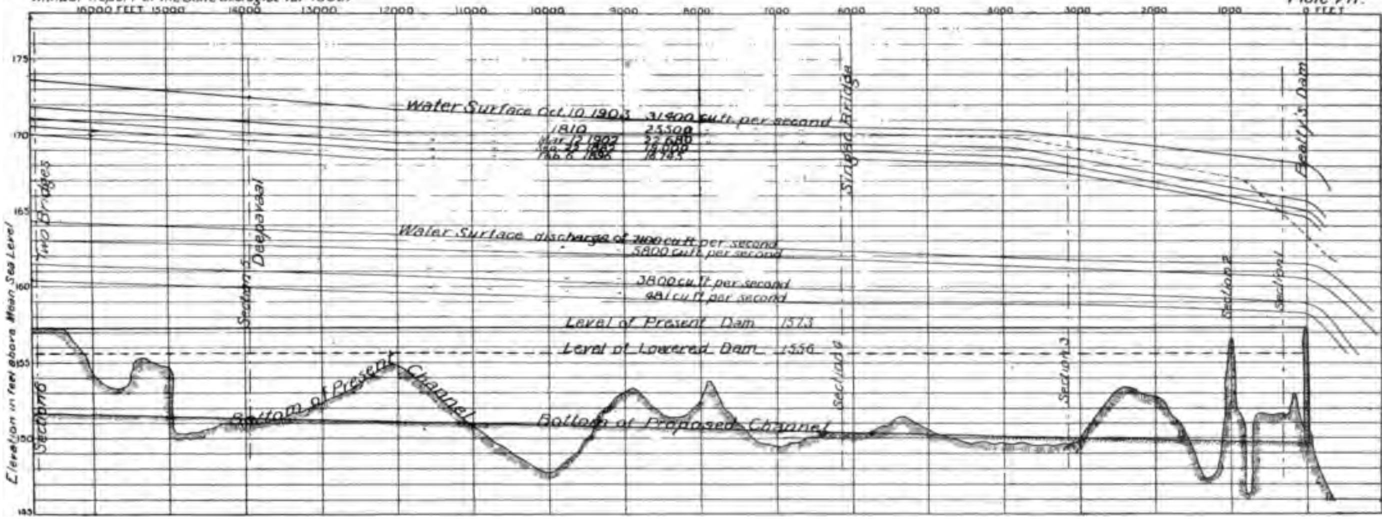
Referring again to Plate V, we have shown the lands submerged immediately above Little Falls. The area of lands submerged, shown on the map by a blue tint, amounts to 22,323 acres. There were, of course, other lands, such as the Great swamp above Millington, and the flats between Millington and Chatham, also submerged, but these other areas have no direct relation to the problem in hand, and have not been considered by us. Their only effect is to make the upper Passaic discharging past Chatham a more tardy and less violent stream than the other branches. The discharge of the Passaic below Little Falls, however, is affected only (1) by the channel from Two Bridges to Little Falls, which limits the discharge, and (2) by the area of flat lands shown on Plate V upon which the floodwaters accumulate during the early part of a flood.

Referring to Plate IV, it will be observed that the Pompton reached its maximum and was falling some 26 hours before the Passaic reached a maximum at Dundee. The Pompton represents about half of the total watershed above Little Falls.

EFFECT OF THE PROPOSED DRAINAGE WORKS ABOVE LITTLE FALLS ON THE HEIGHT OF FLOODS.

The effect of the works begun about 12 years ago for the drainage of the flats above Little Falls in increasing or otherwise affect-

Plate VII.



PROFILE OF PASSAIC RIVER, TWO BRIDGES TO LITTLE FALLS, SHOWING PRESENT CHANNEL, SLOPE OF WATER AT VARIOUS STAGES, AND PROPOSED IMPROVEMENT.

ing the height of great floods on the Passaic was treated at length in the report of 1902. The subject is one which must be considered in connection with any proposed method of controlling the Passaic floods; consequently, I repeat in this connection the considerations which have led me to the conclusion that such drainage works, as they are planned, can have no important effect on the flood-flow, excepting to slightly diminish the height of such floods.

In the agreement made by the Commissioners with the Beattie Manufacturing Co., the following points are fixed as to the extent of the proposed improvements at Beattie's dam and in the channel up to Two Bridges. The dam is to be lowered 20 inches, the channel of the river above the dam to be excavated to a depth of not less than 5 feet below the lowered dam, and to a width of not less than 200 feet. The bar at Two Bridges is to be excavated to a depth of not less than 4 feet below the crest of the lowered dam, and to a width of not less than 200 feet below and 100 feet above the mouth of the Pequannock or Pompton river. It is also agreed to remove such obstructions in the Passaic, between said dam and the reef at Two Bridges, as shall insure a clear waterway of a width of not less than 200 feet, and a depth conformable to a grade line which at said dam shall not be less than 5 feet, and at Two Bridges not less than 4 feet below the level of the crest of the lowered dam. Flood-gates are also to be inserted at the dam.

It will be noted that this agreement merely fixes a minimum improvement. The extent of the improvement, however, cannot very much exceed this, owing to the cost. My report of 1894, to the Committee on Drainage of the Board of Managers of the Geological Survey, pointed out that the most that could be done, keeping within the limits of a practicable cost, would be to increase the channel width to 250 feet and make its depth, at Two Bridges, 4 feet below the crest of the dam, and 6 feet below the crest just above the dam, thereby giving a grade or slope to the channel of .12 in 1,000, which we found to be desirable. The side slopes of this rectified channel we made one perpendicular to one and one-half base. There is little doubt that even this scale of improvement very materially exceeds in

cost the funds which will ever be available for the work, but for the purpose of this discussion we assume that the work may be completed to this extent in order to show the maximum possible effect on the height of floods. The proposed improvements of the channel are shown in profile on Plate VII.

The result of such improvements would be a slightly increased cross-section of the river, and what is more important, a lower value of the co-efficient of roughness, giving a higher velocity for a given slope. Our surveys and investigations show that the present obstructed channel has a coefficient of roughness, "n" in the Kutter formula, of .032, and it may be safely assumed that the improved channel would reduce this to .025. A lower value than this could not reasonably be expected during flood discharge, owing to the crooked course of the river. A computation based on the data furnished by our surveys shows that the effect of the improvements above indicated would be to reduce the height of the water at Two Bridges, for given stages of the river, to the extent shown in the following table:

TABLE VI.

Stream Discharge, in Cubic Feet, per Second.	*Elevation of Surface of Water at Two Bridges.*	
	Present Channel.	*Improved Channel.*
4,000	161.50	158.75
8,000	164.80	161.50
12,000	167.80	164.90
16,000	169.75	166.75
20,000	170.70	168.70
22,000	171.10	169.50

The present bank-full stage at Two Bridges is 4,000 cubic feet per second, and the table shows that for this discharge the elevation of the water will be reduced by the improvement of the channel from its present height of 161.50 to 158.75, or nearly 3 feet. With the improved channel, when the water reaches elevation 161.50 it will be discharging 8,000 cubic feet per second, or just double what it now discharges at that height. For all stages of the river up to 16,000 cubic feet per second, the height at Two Bridges would be reduced by the improvement

about 3 feet, whereas at the maximum flood discharge the reduction would be only the difference between 171.10 and 169.50, or 1.6 feet.

It may be well to urge in this connection that the real benefits of the proposed drainage improvement do not depend on entirely preventing the overflow of the flat lands in time of great freshets. Such prevention would be not only financially impracticable and dangerous to Paterson, but it may be doubted if it would be entirely desirable for the lands. They are considerably enriched by the sediment deposited at such times. A lowering of the water surface at Two Bridges 3 feet during stages between 3,000 and 8,000 cubic feet per second would be of very much greater benefit than the prevention of overflow by occasional high freshets. Data recorded in the Report on Water-Supply show that the stream is between these stages, on the average, over six weeks of each year, while it exceeds 8,000 cubic feet per second less than four and one-half days each year. For weeks and months these lands are now saturated, not by extreme floods, but when the stream is slightly swollen, or during the tardy discharge of the waters at the end of a freshet, and it is this condition which causes sourness, prevents the raising of useful crops, and produces malarial or miasmatic diseases. The lowering of the river 3 feet during such times would almost entirely remove these serious blights from the Central Passaic Valley.

The profile of the river, Plate VII, shows plainly that at the higher flood stages Beattie's dam is not a controlling point. It will be noted that the steep flood slope extends a distance of 4,000 feet above the dam, and the observed height, together with a computation at the cross-sections, made by means of the Kutter formula, show that this control rests with the entire channel, from the dam up to Two Bridges, but is especially affected by the reefs and constricted channel between Singac and the dam. Indeed, for the higher flood stages, Beattie's dam could be entirely removed without causing any appreciable difference in the height of the floods or the maximum discharge of the river.

It was intended by the Drainage Commissioners to put floodgates in the dam, and one of the questions investigated by the Committee on Drainage of the Geological Survey was the proper

size of these gates and their effect. The result of careful computation showed that a capacity of flood-gates in excess of 4,000 cubic feet per second would be useless, and that even with the improved channel the height of floods at Two Bridges would not be affected to any practicable extent by the existence of such gates. At the higher flood stages the discharge would be controlled entirely, even after improvement, by the capacity of the channel from Two Bridges to Little Falls. The effect of such gates, however, would be very beneficial at lower stages of the river, keeping the water level at Two Bridges lower at times when the meadows are now soured by deficient drainage, although not actually submerged by floods.

Since the rate of discharge of the main stream depends entirely upon the height at Two Bridges, whether the channel be improved or not, the question whether the proposed improvement will increase the flood discharge will be determined by ascertaining if, after improvement, the waters at Two Bridges will rise high enough to produce a discharge greater than the present maximum. By referring to Plate VIII, which shows the movement of the flood of 1902, the reader will be enabled to follow the reasoning on which we base our conclusions that no such increased flood discharge can occur. We have seen in our analyses of the several floods that the maximum discharge of the Pompton, at Two Bridges, is reached usually about 33 hours earlier than the maximum of the main stream below Two Bridges, and that the channel below Two Bridges is at present insufficient to carry off the Pompton waters as fast as they come down to Two Bridges, so that these waters are held back and driven up stream into Great Piece meadow to augment the flood-waters coming down from the southerly branches. The improved channel, because of its greater capacity, will carry off a larger volume of these Pompton waters during the early hours of the flood, and thereby decrease the accumulation of water on Great Piece meadow, making it impossible for the water to rise as high at Two Bridges after improvement as it now does.

Taking the diagram of the flood of 1902, Plate VIII, we estimate that the rise of the stream after improvement will not differ materially from that observed for the present channel, as shown

by line "a," until the discharge has reached 12,000 cubic feet per second, because during that period the rise of the Passaic was uniform and controlled by the steady swelling of the several branches, which had not yet begun to rise in a violent manner; but from that time forward the discharge by the new channel, shown by line "d," would have been accelerated more rapidly than with the old channel, because of the rapid rise of the Pompton, and, by 6 A. M. of March 1st, we estimate that it would have reached 21,000 cubic feet per second. Continuing at this rate until noon of the 2d of March, it would have disposed of 569,160,000 cubic feet of the waters accumulated on the flats, or about one-third of the whole; consequently, it would have been impossible for the stream to rise at Two Bridges as high as it did before improvement. We estimate that it would not have increased above 21,000 cubic feet per second, but with adequate improvement of the upper channel it would have been maintained at about this rate until 10 A. M. of the 3d, after which it would steadily decline. It will be noted that during this flood, after improvement, the flow of the Pompton is taken care of as fast as it comes down, and that the waters from the southerly branches, or the Upper Passaic, the discharge of which is shown by line "e," will consequently come down more rapidly at the start, but are estimated to reach a maximum discharge almost as great and at about the same time that it actually occurred with the existing channel, as shown by line "c," after which there will be a steady decline as the waters are discharged from the flats.

It may be thought that the fact that the water at Two Bridges would be maintained at a lower level after improvement, should cause a greater slope of the water surface through Great Piece meadow, and consequently an accelerated discharge of the waters of the Upper Passaic; but it will be found that the reduction of depth over the flat, and consequent reduction of the hydraulic mean radius, will effectually prevent any such acceleration, and that consequently a very considerable improvement of the upper channels will be absolutely essential to maintain the flow at even as high a stage as we have estimated.

The result of our earlier studies, confirmed by the history of the floods of 1896 and 1902, indicate clearly, therefore, that any drainage of the wet lands which is financially practicable, or which is necessary and desirable, can be carried out without increasing, but actually decreasing the rate of discharge of floods on the lower river. In order to emphasize the impracticability of any scale of improvement which would imperil the lower river, it may be well to point out that the cost of an improvement on a scale which we have assumed in the above studies would be, for the work below Two Bridges alone, $192,500, while in order to make this improvement effective above Two Bridges it would be necessary to spend at least enough more to bring the total up to $250,000, a sum which is far more than the Drainage Commission has ever contemplated. While an improvement to this extent would be entirely safe and desirable, a more moderate scale of works could nevertheless be made effective and useful.

METHODS OF CONTROL.

Two possible methods of controlling the floods on the Passaic present themselves for consideration. One of these was suggested in the report of last year, and consists in the construction of large storage reservoirs to hold back the flow of the river to such an extent as to reduce the flood discharge to a harmless maximum. A second plan consists in temporarily impounding the water to throttle down the discharge to a maximum of about 17,000 cubic feet per second, which could be discharged without damage by the lower channel through Paterson, and then allowing the accumulated waters to flow off gradually. The plan of storage reservoirs would be more costly to make it entirely effective, but would have the advantage of adding largely to the flow of the stream during dry weather. The plan of temporarily throttling down the stream would flow no lands permanently, but would increase by about 9% the area subject to occasional flooding and would also increase the length of the period of flooding.

Control by throttling the discharge at Little Falls.—We will consider first the practical application of a system of throttling

down the floods without creating a permanent lake or storage reservoir. We find only one point which is entirely suited to the erection of a dam or barrier which would exercise a proper control, and that point is within 1,000 feet above Beattie's dam at Little Falls. At this point the valley is narrow, and the dam would be founded throughout on trap rock and could be made as enduring as the trap reef itself. At its highest it need not exceed 22 feet, the top being at an elevation of 180 feet above the sea. To make it secure beyond peradventure, it should be given a large margin of strength over that which would be considered necessary for an ordinary dam. Such a dam would hold the water back if necessary at an elevation of 180 feet above mean sea level, an elevation which would be sufficient to impound 3,840,000,000 cubic feet in addition to what accumulated on the flats last October. It should be provided with open sluices having no means of closing, consequently always in operation. They would then have acted as follows during such a flood as that of last October: The discharge through the sluices would have steadily increased up to 17,000 cubic feet per second, which would have been reached 110 hours after the beginning of the flood. The accumulation in excess of the natural maximum accumulation at this time would have been 1,600,000,000 cubic feet, raising the pond back of the controlling dam to elevation 177 or a little less. The discharging sluices would have an area of about 900 square feet, as the maximum head would be 11 feet. These openings should be placed below the ordinary summer level of the river, so as to leave the flow at ordinary stages unrestricted.

Now, the area of land flooded last October, between Little Falls, Chatham, Whippany and Pompton, amounted to 22,323 acres. With such an impounding dam as is now proposed, this area would be increased by only about 800 acres. If we acquire the right to flood 3 feet higher, or to 180, we shall need but 1,900 acres in addition to what is now flooded at times. This additional land would include a few houses and other improvements, and the land which is now flooded would be flooded a little longer time than at present, a little over three days longer during such a phenomenal flood as that of last October.

The effect upon that flood and those of 1902 and 1896 is shown graphically in Plate IX. The maximum discharge for March, 1902, would be reduced to 14,000 cubic feet per second, and for February, 1896, to 12,400 cubic feet per second; while for the flood of last October, the greatest on record, it would be but 17,000 cubic feet, a discharge which would be entirely harmless to interests below Little Falls.

The damages to land resulting from such a method of controlling the river would be this additional flooding of the lands now flooded, and occasionally, at long intervals, the flooding of 1,900 acres of land not now subject to flooding. The additional damage to land which is already flooded would be most liberally estimated at $20 per acre. As a matter of fact, this wet land has not at the present time an average value exceeding $20 per acre. The damage to the 1,900 acres of additional land which would be made subject to flooding, and its improvements, would be liberally covered at $100 per acre, which is about the full value of the property. Other damages which must be considered would be to the Delaware, Lackawanna and Western railroad, and the New York and Greenwood Lake railroad, which pass through the flooded area. Four and one-half miles of the Delaware, Lackawanna and Western railroad would have to be partially raised and partially re-located on higher ground, which could be done without impairing the alignment, and the cost of which would not exceed $90,000. The New York and Greenwood Lake railroad from Little Falls to Pequannock, a distance of five and one-half miles, would also have to be re-located and raised, unless an arrangement could be made by which this road beyond Little Falls could be abandoned and the upper end operated in connection with the New York, Susquehanna and Western railroad. If this could not be arranged, the re-grading and re-location of the road would cost about $75,000. The land flooded is almost all farm land, pasture land and wet meadow. This and the few improvements interfered with are subject to flooding under present conditions, a fact which should be considered in estimating damages.

The entire cost of executing the works necessary for throttling down and holding the river at a maximum discharge not exceed-

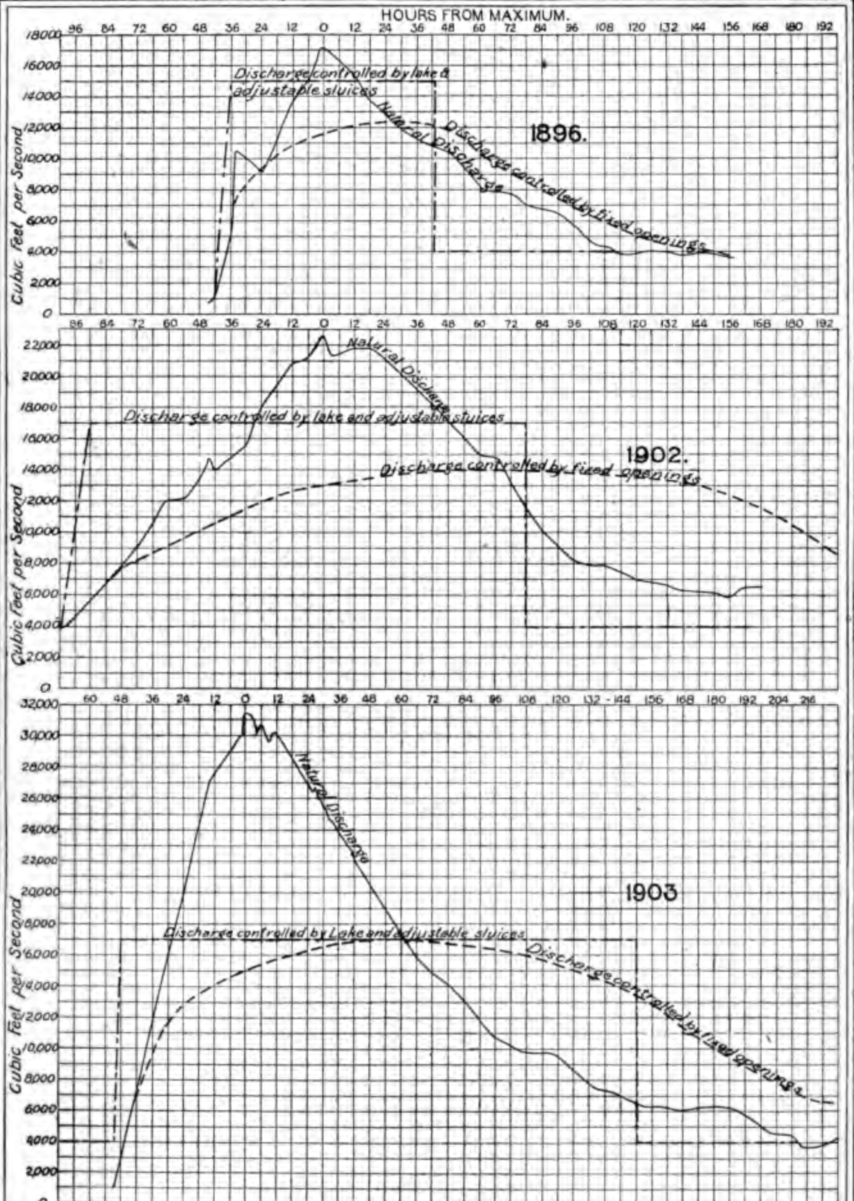


DIAGRAM OF PASSAIC FLOODS SHOWING EFFECT OF PROPOSED CONTROLLING WORKS.

ing 17,000 cubic feet per second may, therefore, be estimated approximately as follows:

Land damages—	
22,323 acres flooded three days longer than at present during extreme floods, at $20 per acre,	$446,460
1,900 acres of land made subject to floods, but which is not now flooded, at $100 per acre,	190,000
Re-location of railways,	165,000
Other damages,	50,000
Cost of constructing masonry dam,	225,000
Incidentals and contingencies, 20 per cent.,	215,292
Total,	$1,291,752

When it is considered that this entire cost is much less than the total damage done during a single flood, and that we have had destructive floods now two years in succession, it is apparent that, although this scheme is somewhat bold, and at first sight radical, it is nevertheless entirely feasible and warranted by the conditions.

In practical operation, such a controlling dam would be provided with openings which would have no provision for closing, but which could not possibly, at any stage of the river, pass a greater quantity than 17,000 cubic feet per second. In addition to these permanent openings, others might be provided which would be closed by sluice-gates, in order to insure further regulation of the discharge, and especially to prevent unnecessary backing up of the water during slight floods. The sluices could be so designed that they would not in the least interfere with the ordinary flow of the river, and, indeed, the drainage works now in contemplation, to drain the wet lands, could be still carried out without hindrance.

We have frequently pointed out that such drainage works can in no case prevent or mitigate the flooding of these lands during high freshets, and that the real intent of the drainage is to promptly dry up the lands after the flood has subsided; whereas, at the present time, the flats often remain saturated with water for weeks and months together. Paradoxical as it may seem, therefore, the provision for holding back the water is not incon-

sistent with the completion of the drainage, and the only effect detrimental to the low lands would be, as already noted, to prolong the flooding about three days during the most severe floods.

The changes in the railroads which we have mentioned should not prove a serious barrier, as these railroads are both subject to flooding under present conditions, and were greatly damaged by the flood of last October, traffic being interrupted for several days, so that they would benefit substantially by the proposed raising of their grade above high-water mark. I have not mentioned the Morris canal. This would also be flooded for a distance of about four miles, but the most that could occur would be a temporary interruption of traffic, which is, in any case, light, while it is probable that in the near future the canal will be abandoned.

The map, Plate V, accompanying this report shows, by a blue tint, the land which was submerged by the flood of last October, and also shows, in red, the outline of the additional lands, the right to flood which would be acquired, although this is three feet higher than the water would have been raised last October, by the proposed controlling dam above Little Falls. The profile of the river, Plate VI, also shows the high-water level through the flats during the flood of last October, and the high-water level represented by elevation 177 to which the water would have risen if the proposed controlling dam had been in operation. At the height of the flood the difference of level above and below the controlling dam would have been about 11 feet, and the permanent openings, consequently, should have sufficient size to enable them to pass 17,000 cubic feet per second with a head of 11 feet. Inasmuch as the maximum height of the water back of the controlling dam last October would have been but 177 feet elevation above the sea, while the top of the dam and the right of flowage extends to elevation 180, such controlling works could control a much greater flood than the highest ever known.

I have thoroughly examined the valley above Little Falls at higher points, and find no location at which the foundations are so good, or the control would be so effective, as at this point within 1,000 feet of Beattie's dam; and a dam at this point, as I

have stated, could be made safe beyond peradventure, owing to the excellence of the foundations.

Control by permanent lakes or storage reservoirs.—The same dam which I have proposed for the control of the floods by throttling might be converted into a permanent storage dam with sluices regulated by gates. Such a great storage lake would exercise control as follows: Taking its normal water-level at 180 elevation, the shore-line would be as represented upon Plate V by a red line. It would be drawn below that level only to maintain the flow during dry seasons, while in great floods it could rise to about 186. At the beginning of a flood the superintendent at the dam, being informed as to conditions upon the several branches, would at once throw open the sluices to a discharge of from 15,000 to 17,000 cubic feet per second, according to the probable extent of the flood. This would anticipate the flood to some extent, and draw down the lake before the height of the flood, as shown by the diagrams of Plate IX. In such a flood as that of 1903, the inflow to the lake would have been, for the first 90 hours, 10,944,000,000 cubic feet; the outflow through the sluices would have been for the same time 5,508,000,000 cubic feet. The difference of 5,436,000,000 cubic feet would have accumulated in the lake, raising it to a maximum height of 184 feet. Continuing the discharge at 17,000 cubic feet per second would have discharged the entire flood, bringing the lake down to its normal level, in 110 hours, or about 4½ days, from the beginning, as shown by the diagram, Plate IX. This great flood could have been limited to only 15,000 cubic feet per second by this method, and the lake would have risen but 6 inches higher, or to 184.5 feet elevation.

A further advantage to be derived from such a storage lake would be the maintenance of an increased flow of the river at and below Little Falls during the dry seasons, to the great advantage of the water power and the sanitary condition of the river. During the worst drought of which we have record a draught of 6 feet from this lake would have easily maintained the flow of the Passaic at 445,000,000 gallons daily, or 700 cubic feet per second. Under present conditions the river falls to less than one-fifth of

this discharge. This would add fully 10,000 horsepower for 24 hours daily to the effective power at Little Falls, Paterson and Dundee. Power is now rented at these points at from $30 upward per horsepower for only 12 hours daily; and, taking $50 per horsepower as the fair rental value for 24 hours daily, we have a total of $500,000 per annum as the value of the additional power created by the storage dam, assuming the lake to be drawn down 6 feet in the greatest droughts, which will only occur at intervals of upwards of a quarter century. As a further advantage, such a reservoir might be used to create an artificial flood when it becomes necessary to flush and cleanse the river below during periods of low water.

The proposed lake would have an area of 25,500 acres at its ordinary level; when temporarily raised by such an extreme flood as that of 1903, it would for two or three days flood 2,400 acres additional, or less than ten per cent. of its area. At ordinary stages its depth, over 18,300 acres, or nearly three-fourths the total lake area, would range from 6 to 15 feet, the remainder being 6 feet deep or less. The depth could be materially improved by an auxiliary dam across the Whippany, near the highway leading from Hanover to Whippany. Such a dam should raise the waters on Black meadows to elevation 190, making a deep and attractive lake between Madison and Morristown. With this auxiliary dam the area less than 6 feet deep would be reduced to 5,000 acres, or 20 per cent. of the whole; and taking into account its great area, which would allow the winds to continually agitate it and sweep its shores with waves, this depth would be ample to preserve its waters in good condition.

Such a great storage reservoir might be supplemented by the other reservoir on Pompton Plains, created by a dam at Mountain View, to which the writer first called attention in 1884 (see Engineering News, April 12, 1884), and which was referred to in the Report on Water-Supply (page 159). A dam at Mountain View, 2,200 feet long, and 57 feet high above the river, would flood Pompton Plains to elevation 220, and the reservoir would have an area of 11,520 acres, with a depth of from 20 to 50 feet, with little shallow flowage. It would create a supply of 332,000,000 gallons daily of potable

water. As the lake would be at elevation 220 feet above sea-level, all the lower parts of the populous region east of the Watchung mountains could be supplied from it by gravity, while for the higher portions the water could be pumped with a small fraction of the water-power created at Little Falls by this storage system. This Pompton Plains reservoir would greatly reduce the fluctuations in level of the previously described reservoir on the southern branches, created by the dam at Little Falls.

Such a development of the Passaic by storage would not only control its floods, but would, in a magnificent way, utilize its waters to benefit the people of the State. Taking the power now in use at Dundee, Paterson and Little Falls at about 4,800 horsepower, the present system of diverting the river to supply our cities will steadily reduce and ultimately destroy the value of this power; whereas the above plan of utilization will enable us to draw all the water now used by our cities and still leave power now in use and new power created aggregating 14,000 horsepower for 24 hours daily. Ultimately, when the entire Pompton river shall have been appropriated, yielding 304,000,000 gallons daily, for public water-supply, we shall still have 7,000 horsepower for use in our manufacturing cities.

The cost of such a storage system would, of course, be much greater than the cost of the throttling dam first described; but since the additional power created would alone pay five per cent. interest on $10,000,000, which is much more than the total cost of the reservoirs, it is almost certain that fuller study will show it to be of the two the more profitable and advantageous plan.

As compared with any plan for providing for flood discharge by deepening and enlarging the river channel through Paterson and Passaic, either of the plans here proposed is preferable, although improvement of the channel might supplement these plans in the future. It will be observed that the throttling dam first described in no wise impairs any of the valuable water-powers, while the plan of storage greatly enhances their value; whereas adequate reduction of the height of the flood through Paterson, by channel improvement, would, in our opinion, call for the destruction of the valuable Dundee water-power, in-

PART III.

Forest Fires in New Jersey During 1903.

By F. R. MEIER.

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HOW TO ESTIMATE FOREST FIRE LOSSES.

Without an examination of the burned areas on the ground, it is impossible to give even approximate estimates as to the extent of damage done by the fire. The extent, severity and degree of damage depends upon the kind and character of the growth, season of the year, whether burned by day or by night; whether hot, dry, windy or wet, on the direction of the wind, whether on sandy plains or mountain lands.*

It was, therefore, necessary to visit each tract burned over, and to determine the percentage of damage done by the fire by an examination of the bark of the scorched trees of a sample area. Where the fire had been severe, burning through the bark, an examination at a glance determined the degree of loss; where the outer bark had been severely scorched, slight cuts were made through the bark, at several points around the trunk, to determine whether it had been killed. If the inner bark was found to be brown, as also the surface of the sapwood, such trees were not expected to recover. Trees with a portion of the bark alive, say from one-third to one-half of the circumference, may recover,

* Pineries on plains, on account of the dry, sandy soil, are visited by more severe fires than the mountain forest. Fires burn more rapidly up-hill than down-hill.

Fires generally fall off in violence during the night and become stronger again after sunrise; this is due to the fact that the wind usually slackens at night and to the nightly dews.

The dry west and southwest winds of April and May, in which months most of the fires occur, cause the most dangerous and extensive fires.

Fires do more damage after the sap begins to move.

although their growth will be retarded to a considerable extent, and in some cases such trees may, within a year or so, succumb. Trees thus affected are called "injured" in the estimate of damages.

The actual damage to the forest by fire greatly exceeds the value of the merchantable timber which has been killed. The fact that the young, unmarketable growth is destroyed is a loss which must also be reckoned in dollars and cents. This, however, cannot be done except when two things are known. These are, 1st, the average age, size and number of immature trees which were killed, and, 2d, the length of time it would have taken them to reach merchantable size. With this data at hand the calculation of damage done is then simply one of compound interest, in which the value of immature trees is reckoned on the basis of their value at maturity, and the length of time which would have elapsed before they were mature.

When the fire has burned so severely that the burned area cannot restock itself naturally, then the cost of planting is to be added in the calculation of damages. Fortunately, the regenerative power of the New Jersey forest, especially of the pines in South Jersey, is excellent, and only in two instances was it found necessary to take this factor into consideration while estimating the extent of damages. A calculation as to the indirect damages, as that done to the soil, although in many cases heavier than the direct losses, is not included in the estimate of losses. Reference has been made as to this in the discussion of humus.*

BEHAVIOR OF OLD AND YOUNG GROWTH AFTER FIRE.

On account of the thick, corky bark, old pitch pine withstands a great deal of fire, an ordinary light surface fire blackening the tree without doing much injury to the growth, while it has the power to recuperate rapidly. The shortleaf pine, while also being able to resist fire, does not recuperate as readily as the pitch pine. Heavy fires will kill the trees. Pitch pine sprouts from the collar after the fire has killed the tree. These sprouts grow

*No court will give any award for such indirect damages.

slowly, are crooked and knotty, and seldom have great commercial value. The more valuable shortleaf pine does not sprout.

The white cedar is very easily killed by fire, and will not sprout. Fortunately, the swamps are a great protection, and only "hot fires" with strong winds enter the interior of a swamp. Trees on the edges are frequently killed, however, from the severe heat of surrounding fires, even when themselves untouched by the flames.

The effect of fire on the oaks is varied. Only very severe fires will kill the old oaks outright; young growth is easily killed. If young and strong, they all sprout after the fire has killed their trunks, but the sprouts, like most other trees under the same conditions, do not always make large or sound trees. When the killed trees decay, a scar is usually left at the base of the tree, in which rot sooner or later will begin. White oak is not as susceptibe to the rotting as red and black oaks; yet is more easily killed or injured by fire than the Spanish, black and scrub oaks. Of all the oaks the black-jack withstands the fire best. The hickories are all sensitive to fire, but if young will sprout; the white hickory possesses the best sprouting power of the hickories after being killed by fire, and trees up to 8 inches in diameter send up sprouts freely.

Chestnuts sprout freely and vigorously after being killed by fire. Owing chiefly to fire, chestnuts from sprouts have degenerated; that is, the timber begins to rot at the heart on attaining a certain age, chiefly when 40 or 45 years old, and the growth becomes somewhat stunted in general.

The effect of even light surface fires on both seedlings and coppice is disastrous, killing outright most growth from 1 to 12 feet high. The thin-barked young stems of all species are severely scorched so that they die down soon after the fire. The greatest damage is done in the periodic destruction of from 1 to 10 years' growth of seedlings and coppice. Ordinary fires often scorch older trees severely enough to check the growth or result in unsoundness at maturity.

FIRE DESTROYS THE MANURE OF THE FOREST—THE HUMUS.

Humus, which is an accumulation of decayed matters, such as leaves and twigs which are shed by the trees and undergrowth, is one of the most important requirements of forest growth. Humus is the manure of the forest. It enriches the ground and keeps it moist. In sandy, dry regions, like South Jersey, it is of great importance. If burned, the soil dries rapidly, and forms a hard crust, preventing germination of those seeds in the ground not killed by fire. Humus makes soil, it makes binding soil more porous, and loose soil more binding. By binding the soil it prevents the important mineral materials from being washed away. It has been proven that humus has the power of absorbing moisture and holding at least four times its own weight in water, as well as preventing rapid evaporation; it has also been established that humus loses two and one-half times less water than forest soil on which humus has been burned.

To reckon the loss of humus, caused by fire, in dollars and cents, is a somewhat difficult matter, but a few figures are given to indicate the extent of damage through its destruction. On the average, there are annually added to the soil by the fall of leaves in a dense forest, from 1,800 to 4,500 pounds per acre, containing, according to kind and condition of growth and soil, from 24 to 220 pounds of mineral matter, potash, phosphoric acid, magnesia, lime, etc., and 12 to 60 pounds of nitrogen, the whole equivalent to not less than 25 cents' worth of commercial fertilizer. If, then, the fire destroys the humus the soil is impoverished and becomes dead.

While it is well known, that both a single "hot" fire, and repeated light surface fires destroy part or all of the humus, few people realize the extent of harm to the forest floor. As long as the merchantable growth is not killed outright, people look at light surface fires—destroying the humus—with indifference and even approve of the same.

EFFECT OF FIRE ON REPRODUCTION, SUCCESSION AND COMPOSITION.

There is still another ill effect of fire, that is, the serious injury to the reproduction, succession and composition of the forest.

Forest areas, repeatedly burned over, will finally have a growth consisting almost entirely of sprouts, and of these only the hardiest will attain tree size. Moreover, these are often of inferior kinds. By this it is not meant that no pine or hardwood seedlings whatever, will be found on such areas, but they are scattered about in clusters and are of poorer quality.

It is often due to fire that the hardier and less valuable oaks take the place of pine, also that black oak takes the place of the more valuable white oak and hickory.

FIRE INVITES INSECTS AND ROT.

Fires scorch spots near the bases of trees and cause the death of the generative tissue. The bark over the spot then becomes loosened, or falls off, and the tree presents on its surface a layer of dead sapwood. The sapwood of most trees is then subject to the attacks of insects, borers and beetles. If the bark is merely loosened, insects will quickly enter the spot and will bore sometimes into the heart-wood. Through these openings air and water enter, and decay begins. In this way the entire interior of the base of the tree may become hollow, while the bark, remaining intact, exhibits no signs of the rottenness which is within. If the bark falls off immediately from the burned spots, the dead sapwood is then directly exposed to rot, and fungi, in the shape of punk or mushroom-like excrescences, grow upon it. The final result is that the storms blow down these trees, even such whose trunks above the rotten spot are perfectly sound.

OTHER ILL EFFECTS OF FIRE.

Fires discourage land owners in the improved handling of their woodland; they discourage owners of barren land in tree

planting. When fire has killed trees, particularly on larger tracts, people seem to regard the dead wood as public property, so that theft is encouraged. Where fire frequently occurs it tends to depopulate and impoverish those sections and destroys the game.

FOREST FIRE LEGISLATION IN VARIOUS STATES.

Several States have enacted forest fire legislation, notably New York, Pennsylvania, Minnesota, Wisconsin, Maine, New Hampshire.

New York appoints a fire warden for each town in counties having State land. The State pays one half and the county the other half for the fire warden's service. The chief fire warden is a State officer.

Pennsylvania makes the constables fire wardens, the State paying one half and the towns the other half of their expenses.

In Minnesota the town supervisors are fire wardens. These wardens receive $2.00 per day for services, not exceeding 15 days in the year. The State pays one third and the county one third of the expenses.

The other States having forest fire laws have followed, with some modifications, the examples of New York and Minnesota.

[In New Jersey the townships have power to appoint a fire marshal and appropriate money for fighting fires. The State doubles the sum appropriated by the township, up to $100 for the township and $200 for the State, so that there is $300 available for preventing and extinguishing forest fires in such townships as have accepted the provisions of the law. The New Jersey law also provides for an investigation, by justices of the peace, of the origin of fires upon application by ten freeholders, and for punishing violations of its sections regarding burning brush, grass, etc.* At the present time, however, only three townships have accepted the provisions of the law.—H. B. K.]

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* For a fuller statement regarding the law, see the Administrative report.

FOREST FIRE STATISTICS OF FOREIGN COUNTRIES.

Prussia, with 7,000,000 acres of State forest, has had an annual average destruction by fire in the last twenty-five years of 1,400 acres, or .02%, or about one acre in 4,500. Over 50% of this total area is stocked with pine on sandy plains. The number of yearly fires vary from 15 to 250, but they are promptly extinguished, as is evident from the small extent of the burned area.

Bavaria has over 2,000,000 acres of State forest, 75% of which is coniferous. The number of yearly forest fires vary from 2 to 80, with an average yearly burned-over area of about 200 acres, or one acre in about 13,000, causing a loss of about $1,200.00. The principal causes are carelessness of excursion parties.

Compare this record with New Jersey, which has about the same extent of forest land. Here there were, last year, 79 fires, which burned 85,046 acres, with a direct loss to the timber of $305,744.00.

On 3,800,000 acres of State and Fund forest of Austria, 75% conifers, the yearly average for the last ten years is 510 fires, burning over 3,500 acres, 60% of these fires being caused by carelessness.

Saxony suffers hardly any loss from forest fires on its one half million acres of State forest, and the damage is rarely more than $300.00 per acre per year. Spruce is the prevailing tree. The causes of the fires are chiefly carelessness of pipe and cigar smokers.

On its 800,000 acres of chiefly coniferous State forest the Duchy of Baden has on an average yearly 60 forest fires, damaging not more than 100 acres, the principal causes being negligence of smokers.

The yearly average loss by forest fires in the kingdom of Würtemberg on over 400,000 State forest, stocked with 40% broad-leaved trees and 60% coniferous trees, amounts to $600.00. Smokers are the principal causes of the fires.

The average annual forest fires in Hessen-Darmstad on 165,000 acres of State forest, stocked with 60% broad-leaved and 40%

coniferous trees, do not run over more than 45 acres, the average number being 50 fires. Again the principal cause is carelessness of smokers.

Damage on the 140,000 acres of State forest of Denmark, 50% conifers, is very slight; general carelessness is the cause of the fires, with an occasional fire set by railroad locomotives.

In German forests the forest is divided into compartments; each compartment being surrounded by fire lines 8 to 40 rods wide. These fire lines are patroled and kept free from inflammable material by annual burnings or by sowing to grass, the purpose being to confine the fire within the compartment and to furnish a base from which to fight it. Private forest owners in Germany have the right to call out assistance to fight forest fires, which assistance is obligatory to every citizen.

In India measures have been taken to protect 28,000 square miles of State forest with success. Here the grass is frequently from 6 feet to 8 feet high, and in addition the leaves of many Indian trees, such as the teak and the sál, fall in the early spring, and when dry are very inflammable. It is a most dangerous forest, and yet the Indian forest department fights these fires, and succeeds in a measure. The fire lines here are often 400 feet wide.

There are fire insurance companies in Germany which insure forest properties according to age, species and local danger. The fire insurance value of young stands is calculated by a discount with a 5% interest rate on the final harvest value; for mature stands the actual present value is supposed to persist for ten years. The premiums based for each $1,000.00 insurance value are in the average:

For broad-leaved forests,	$0.85
For mixed conifer and broad-leaved forest,	1.20
For conifer pure,	2.00

The minimum rate is 45 cents, the maximum $4.00 per $1,000.00 value.

In Belgium there are many small private forest owners, and insurance against damage to forests by fire can be effected at reasonable rates:

60 cents per $1,000.00 for broad leaved woods.
$5.50 per $1,000.00 for conifers under 20 years old.
$4.75 per $1,000.00 for conifers over 20 years old.

The above statistics are of countries which have taken practical measures toward forest protection. The statistics show that while the number of fires in some countries is great, the extent of damage is small owing to effective measures to extinguish them promptly.

RECOMMENDATIONS.

The members of the State Geological Survey, who have studied the question of forest fires in New Jersey, have repeatedly called attention to the need of State action if the forests are to be preserved. The following recommendations do not differ essentially from those made in previous years, but are repeated to emphasize the necessity of some action.

1. The appointment of a State forester, who would also be chief fire warden, whose duty should be to control all fire wardens, instruct them, and to respond to larger fires; to give advice to owners of forest land as to the protection and best handling of their woodlands, as to tree planting, etc.; he should make forest investigations, and arouse a general interest throughout the State in all matters pertaining to forests and forestry.

2. The appointment of twenty wardens of the first class at $60.00 a year each. They should be so distributed that each should direct four second-class wardens. Their duty would be to repair at once to each fire in their district, and to take charge of the efforts to extinguish it. They should have power to call in other help in case of necessity.

3. Eighty second-class fire wardens, each warden to have fire charge of 15,000 acres; the wardens to receive $25.00 per year each. These wardens should be required to make daily observations for signs of fire and to repair at once to all fires within his limit. These limits should overlap so that several wardens would go to each fire. Power should be given the forest service to enter into agreements with townships for clearing or burning away

the brush along roads leading through woods, thus widening them to act as fire lines.

The suggestions as to fire wardens are for the pineries in South Jersey, some 1,200,000 acres. For the mountain lands in the upper part of the State it would suffice to make town constables fire wardens.

Description of the Fires of 1903.

The following notes are from data collected by a personal visit to each tract and careful observations on the amount of damage caused. So far as possible the cause of each fire was learned and also the efforts made to extinguish it. The fires are numbered to assist in their accurate location on the accompanying map, Plate X.

ATLANTIC COUNTY.

1. May 1st, 1903. A man burning brush started a fire near Oakville, Weymouth township, which burned 2,400 acres of pine and oak. 1,000 acres were covered with a promising growth of pine, 500 with scattered pine and oak, while 900 acres were partly brush land with clusters of pine and oak. The average age was 18 years. All the young growth was killed, and the old trees badly injured. The fire was fought by six men with some success. Average loss, $1.50 per acre; total, $3,600.

2. April 28th, 1903. A man burning brush around a cranberry bog started by a fire one half mile southeast of Doughty Tavern, which burned to South River and to Grassy pond, being two miles long and four miles wide and covering about 5,000 acres. The timber was from 10 to 35 years old; 75 per cent. being pine and 25 per cent. oak. Seven hundred acres were barren land, but 2,000 acres of thrifty pine mostly from seed was killed. All the oak both young and old was killed, while 60 per cent. of the pine over 30 years was injured and 40 per cent. under 30 years was killed. Men from Mays Landing and Weymouth, under the direction of Pennington Taylor, an old woods-

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man eighty years old, fought the fire by backfiring with some success, but no efforts were made to extinguish it until after 4,000 acres had been burned over. Average loss, $2.00 per acre; total damage, $10,000.

3. May 3d, 1903. In clearing land a fire was started one mile east of Richland, and burned 500 acres of pine and oak from 5 to 10 years old, with 25 acres of pine 25 years old. Of the young pine and oak, 80 per cent. was killed, the balance badly injured. The older pines were partly killed and partly injured. In addition a house and barn were burned, the value of which are not included in this estimate. No effort was made to check the fire except where the farm buildings were threatened. Average loss, $3.00 per acre; total, $1,500.

4. April 30th, 1903. Sparks from a locomotive started a fire at Hammonton, which burned southeast towards Weymouth covering 1,500 acres. Eighty-five per cent. of the timber was pine, 10 to 18 years' growth, the balance various kinds of oaks with some young white cedar 12 years of age. The timber was, on the whole, very promising, a great part being seedlings and not sprouts. Ninety per cent. of all the growth was killed outright. Hammonton was for a time threatened, and several buildings were burned which are not included in this estimate. The fire was fought by railroad section men after a greater portion of the area had been burned over. Average loss, $2.75 per acre; total damage, $4,125.

5. April 28th, 1903. A locomotive started a fire south of Elwood station, which burned to Mays Landing, a distance of nine miles, sweeping over 10,000 acres, 8,000 of which was covered with small pine and oak, 5 to 15 years old, chiefly sprouts. Fifteen hundred acres were more or less barren as a result of former fires, and 500 acres were good pine and oak from 25 to 50 years old. Sixty per cent. of the growth was destroyed, 20 per cent. badly injured and perhaps 20 per cent. more or less scorched. White cedars near Weymouth were killed. The fire was fought by railroad section men and farmers with but little success, since the temperature was in the neighborhood of ninety degrees, and the wind blew a gale of 20 miles an hour. Two backfires were set but with poor results, owing to lack of efficient leadership. Average loss, $4.50 per acre; total, $45,000.

6. May 10th, 1903. Another fire due to a locomotive started at Elwood station and burned easterly toward Weekstown over a section four miles long and a mile wide, 2,500 acres. Timber was mostly pine, averaging 15 years old, 90 per cent. of which was killed. The oaks were all killed. The fire was fought by railroad section men and some farmers to protect buildings. Average loss, $2.00 per acre; total, $5,000.

7. May 9th, 1903. In burning turf on a cranberry bog, a fire was started between Weekstown and Mullica pond near Greenbank, which burned 1,900 of pitch pine, white, red and black oak, with some white cedar 8 to 24 years old. 1,100 acres of this area was burned eight years ago. Sixty per cent. of the growth was killed, 30 per cent. badly injured, 10 per cent. scorched. The fire was fought by men in the employ of Joseph Wharton with shovels and sand and by backfiring. Average loss, $2.50 per acre; total, $4,750.

8. May 1st, 1903. A locomotive started a fire at Brigantine Junction which burned south toward McKee City, sweeping over 600 acres, 200 of which were pine 15 years old of poor quality, while 400 acres were more or less barren. It was fought by railroad men soon after it started, but their efforts were handicapped by a heavy wind. It was finally extinguished with shovels and sand. Average loss over 200 acres, $2.50 per acre; total, $500.

9. In April, smokers started a fire about one-half mile east of McKee City station, which burned 25 acres of good pitch pine, 20 years' growth, 50 per cent. of which was killed and the balance badly injured. The fire burned itself out, no effort being made to extinguish it. Average loss, $5.00 per acre; total, $125.

10. In April, a locomotive set fire to the timber near the head of Gravelly run and burned 150 acres, mostly pine barrens, with perhaps 20 acres of good pine and oak 8 years old, which was killed. Loss, $75.

11. May 2d, 1903. A fire, due to a locomotive, burned 125 acres of good oak and pine, 10 years of age, east of Landisville station. Ninety per cent. was killed, no effort being made to extinguish the fire. The same tract was burned eleven years ago. Loss, $4.25 per acre; total, $530.

BURLINGTON COUNTY.

12. April 27th, 1903. A farmer burning brush started a fire near Atco, which burned to Waterford and thence to Atsion, Taunton and nearly to Medford, a strip 10 miles long and 4 miles wide, including 21,000 acres. Fifty per cent. of the total area had a fine growth of pine and oak from 15 to 25 years old, in which there had been no fire for the past 25 years. Ten per cent. was barren and 40 per cent. young and scattered growth of pine and oak. It was a "hot fire," destroying all growth, including two cedar swamps and two cranberry bogs. Several houses and barns were burned and the roof of a church damaged. Although most of the burned tract is in Burlington county, the fire started in Camden. It was fought by fifteen men in the employ of Joseph Wharton, with shovel and sand. Other parties started backfires, which did more harm than good, owing to the poor judgment shown in locating them. Damage per acre ranged from $0.10 to $25.00; average, $5.00; total, $105,000.

13. April 21st, 1903. A locomotive started a fire one and one-half miles northeast of Atsion, between that place and Harris station. It burned 250 acres, 80 per cent. pine, 20 per cent. oak, ranging from 10 to 40 years old, all of which was killed, including 10 acres of short-leafed pine, 40 years old. It was fought by railroad section men with success. Average loss, $3.25 per acre; total, $812.

14. During the last week of June, a fire was accidentally started a mile east of Browns Mills and burned 100 acres of pine and oak, 65 per cent. of which was from seed, and very promising. Thirty per cent. was pine barren, the balance of the area being covered with scattered pines. The timber varied from 10 to 25 years old. The pines were killed and the oaks severely injured. It was fought with shovels and sand with success. Average loss, $2.00 per acre; total, $200.

15. April, 1903. Another fire, origin unknown, burned 75 acres, a mile northeast of Browns Mills. The timber was pine and oak, four years' growth. The tract was burned four years

aog. The fire burned itself out. Average loss, $0.50 per acre; total, $37.

16. April, 1903. Another fire, of incendiary origin, started three miles northeast of Browns Mills and destroyed 90 acres of timber, 65 per cent. of which was promising pine and oak from seed, 10 to 25 years old. The young pines were killed and the old oaks badly injured, but not killed. Thirty-five per cent. of the area was barren. No effort was made to extinguish the fire. Average loss, $3.00 per acre; total, $270.

17. May, 1903. A locomotive along the line of the Pemberton and Hightstown railroad near Cookstown started a fire which burned 10 acres. The tract had various kinds of hard wood, principally oak and chestnut from 5 to 10 years old, not very promising growth, since it had been burned two years ago. Six hundred chestnut rails were also destroyed. The fire was extinguished by section men with shovels. Value of the chestnut rails, $75.

18. May 6th, 1903. A fire was started two miles south of Chatsworth, between that point and Speedwell, in burning brush at a cranberry bog. Four hundred acres of pine and oak, 8 to 20 years old, was burned, 85 per cent. being killed. One and one-half acres of 10 year old white cedar were also killed. This tract was partly burned in 1895. Men in the employ of Joseph Wharton started backfires with good success. The fire burned three days before being extinguished. Average loss, $2.50 per acre; total, $1,000.

CUMBERLAND COUNTY.

19. April 28th, 1903. A man burning brush started a fire in the southern part of Landis township, which burned 5,000 acres, most of which were pine, with some oak, from 10 to 18 years old. Seventy-five per cent. was killed, as well as two acres of cedar. Of the 5,000 acres, 800 were pine barren. The fire was fought by backfiring under the leadership of the township fire marshal. Average loss, $2.00 per acre; total, $10,000.

20. May 1st, 1903. A fire, started by burning brush, occurred two miles west of Mauricetown, in Commercial township, which

burned 100 acres of oak and pine, 10 to 30 years' growth. The oaks were all killed. This tract was also burned 30 years ago. Twenty-five acres of very good yellow pine, from seed, 30 years old were badly injured. The fire was fought by backfiring with good success, 1,000 cords of wood being saved by prompt action. Average loss, $6.50 per acre; total, $650.00.

21. May 7th, 1903. A fire, origin unknown, started four miles west of Millville, burning 300 acres of pine and oak, 10 to 30 years' growth, some of which was of promising growth, some barren. Some of the timber was entirely killed, some partly killed. The fire was fought by backfiring with success. Average loss, $3.00 per acre; total, $900.

22. April 12th, 1903. A little east of Gouldtown, a fire, set by burning brush, burned 500 acres of pine and oak, from 8 to 25 years old. The oaks were killed and pines badly injured. The fire was fought under the leadership of the township fire marshal. Average loss, $1.75; total, $875.00.

23. April 22d, 1903. Two and one-half miles northwest of Millville a fire was started by burning brush. It burned 150 acres of pine and oak, 10 to 30 years old, some of which was entirely killed and some partly injured. Parts of the area were promising growth; 10 acres were barren land. Fire was fought by township fire marshal. Average loss, $3.00; total, $450.00.

24. April 6th, 1903. Southwest of Vineland, on the east side of Maurice river, north of the dam, burning brush set fire to 1,000 acres of pine and oak, 6 to 30 years old. All of the oaks were killed, as were also 60 per cent. of pines over 20 years old and 90 per cent. of pines under 20 years. Part of a cedar swamp was also burned. No real efforts were made toward extinguishing the fire. Average loss per acre, $2.00; total, $2,000.

25. April 18th, 1903. School children picking wild flowers south of Rosenhayn, set fire to 1,000 acres of oak and pine, somewhat scattered, from 8 to 20 years old, which were mostly killed. Two hundred and fifty acres of the 1,000 were barren land. The fire was fought by the township fire marshal. Average loss per acre, $2.00; total, $2,000.

26. April 30th, 1903. Southwest of Rosenhayn an incendiary fire mostly killed 200 acres of scattered oak and pine from 8 to

20 years old. This fire was fought under the leadership of the township fire marshal. Average loss, $2.00 per acre; total, $400.

27. April 29th, 1903. Locomotive sparks started a fire northeast of Vineland, which burned 15 acres of pine and oak, 4 to 35 years' growth. The oak and younger pines were killed. The township fire marshal fought the fire. Average loss, $4.50 per acre; total, $67.00.

CAPE MAY COUNTY.

28. April 10th to 20th, 1903. A fire, started by burning brush, occurred one-half mile from Woodbine, running northwest to Belle Plain and south to East creek, burning 2,000 acres, 1,200 acres of which were good pine and oak, and 800 acres partly barren, partly covered with poor pines and oaks. All the oak was killed, and some of the pines were badly injured, and some partly killed. Moreover, 500 cords of cord wood valued at $2.00 per cord were burned. The fire was fought by backfiring, but not until it had burned eight days. Loss, from $1.00 to $10.00 per acre, average, $5.00; total, $10,000. Total damage to cord wood, $1,000.

29. April, 1903. Two miles south of Woodbine, a fire, started by burning grass, burned 400 acres of good oak and pine timber, 10 to 40 years old, which were entirely killed. In addition, 300 cords of wood worth $2.75 per cord were burned. Average loss, $3.00 per acre; total, $1,200. Loss of cord wood, $825.

30. April, 1903. At Woodbine, a fire, started by a locomotive, burned 120 acres of pine and oak of good growth, 10 to 40 years old. Sixty per cent. of pines, and all oaks were killed. A part of this tract was burned 10 years ago. The fire was fought by backfiring with success. Average loss, $3.00 per acre; total, $360.

31. April, 1903. Two miles from Woodbine, between Woodbine and Tuckahoe, a locomotive set fire to 200 acres of good growth pine and oak, 10 to 40 years old. Sixty per cent. of pines, and all the oaks were killed. Part of this area was burned

10 years ago. The fire was fought by backfiring. Average loss, $3.00 per acre; total, $600.

CAMDEN COUNTY.

32. June, 1903. On the west side of Chiselhurst, a fire, origin unknown, burned seven acres of white and red oak, 50 years old, killing a very fine growth of timber. No effort was made to extinguish the fire. Average loss, $60.00 per acre; total, $420.

The fire, No. 12, in Burlington county, originated in Camden county, near Atco.

GLOUCESTER COUNTY.

33. April, 1903. Near Robanna, a locomotive set fire to 300 acres of very thrifty oak and pine, 10 to 20 years old, which were totally destroyed. This area had never been burned before. No efforts were made to extinguish the fire. Average loss, $3.75 per acre; total, $1,125.

34. April, 1903. Burning grass started a fire west of Broad Lane which burned 60 acres of oak and pine. Eighty per cent. of the oak, 12 to 24 years' growth, was killed, and 20 cords of wood worth $2.00 per cord, destroyed. This area was never burned before this fire. The fire was extinguished by beating it out with brush. Average loss, $4.00 per acre; total, $240. Total damage cord wood, $40.

35. April, 1903. A fire north of Cecil, caused by burning brush, burned 50 acres of oak and pine averaging 18 years old, and 10 cords of cord wood at $1.75. Seventy-five per cent. of the oak was killed. No effort was made to extinguish the fire. Average loss, $2.75 per acre; total, $137. Total damage to cord wood, $17.00.

36. April, 1903. Forty-five acres of oak and pine of 15 years' growth were badly injured, but not killed, by a fire west of Cecil, caused by burning grass. No efforts were made to extinguish this fire. Average loss, $1.00 per acre; total, $45.00.

37. May, 1903. Between Clayton and Janvier, near Scotland run, a fire, started by some unknown cause, burned and killed 400 acres of oaks and scattered pines of very thrifty growth. A part of this area was burned over one year ago (April, 1902). No efforts were made to extinguish the fire. Average loss, $3.00 per acre; total, $1,200.

38. April, 1903. A fire near Downer, of incendiary origin, burned and killed 200 acres of old oaks, 38 years old. The fire was fought by backfiring. Average loss, $6.50 per acre; total, $1,300.

MONMOUTH COUNTY.

39. June, 1903. Four miles west of Belmar, a fire set by smokers burned 550 acres, mainly oak with some scattered pine. Forty acres of fine oak 60 years old were badly injured; 45 acres of thrifty oak 40 years old partly killed, and the young oak and pine were killed. About 80 acres were burned over four years ago. The fire was fought with success by backfiring and plowing furrows to act as a fire lane. Average loss, $7.00 per acre; total, $3,850.

40. June 4th, 1903. At South Eatontown, a fire, started by tramps, burned and killed eight acres of oak and pine, two years old. This tract was burned over two years ago. The fire was beaten out with brush. Average loss, $0.50 per acre; total, $4.00.

MORRIS COUNTY.

41. May, 1903. One-half mile north of Mt. Freedom, southeast of Youngstown, a fire, cause unknown, burned and badly injured 1,000 acres of chestnut, oak and hickory. Two hundred acres of chestnut from 25 to 60 years of age were killed. This tract had never been burned over before. An effort was made to extinguish the fire, with but little success. Average loss, $4.00 per acre; total, $4,000.

42. October, 1903. Sparks from a locomotive started a fire near Tabor, which burned and partly injured 10 acres of chestnut

and oak, 40 years old. The fire was extinguished by railroad section men. Average loss, $1.00 per acre; total, $10.00.

43. October, 1903. Another fire near Tabor, due to a locomotive, burned 15 acres of chestnut and oak, 40 years old, which were injured but not killed. This fire was also extinguished by railroad section men. Average loss, $0.75 per acre; total $11.00.

44. June, 1903. A tramp started a fire west of Dover, which burned 350 acres, mainly oak and chestnut, 40 years old, and killed 40 per cent. No efforts were made to extinguish the fire. Average loss, $4.50 per acre; total, $1,575.

45. During the first week in July, a fire, started by smokers, occurred two and one-half miles north of Rockaway, west of Beach Glen, which burned 150 acres of 20 year old growth of oak and chestnut, 20 per cent. of the most promising growth being killed. The fire was fought by backfiring with good results. Average loss, $4.00 per acre; total, $690.00.

46. During the first week in July a fire started intentionally occurred one mile east of Hibernia, and burned 175 acres of oak and chestnut sprouts of 30 years' growth. Ten per cent. was killed and the balance more or less injured. The fire was fought by backfiring. Average, $3.75 per acre; total, $656.00.

47. May 21st, 1903. South of Denmark pond, between the pond and railroad, a fire, due to a locomotive, burned 450 acres, mainly of oak and chestnut, from 10 to 60 years' growth. The young growth was destroyed, and 70 acres of good-sized oak were partly killed. No efforts, as for as known, were made to extinguish the fire. Average loss, $6.00 per acre; total, $2,700.

48. May, 1903. East of the road from Oak Ridge to Petersburg, at the intersection of the Oak Ridge-Petersburg and Oak Ridge-Green Pond road, fire set by smokers burned and slightly injured 225 acres of good heavy chestnut. No efforts were made to extinguish the fire except to save buildings. Average loss, $0.75 per acre; total, $169.00.

49. May 18th, 1903. One and one-half miles southwest of Newfoundland, a fire, started by campers, burned 1,200 acres of oak and chestnut, 20 to 40 years old, killing 80 per cent. The fire started on the top of the mountain and burned very rapidly. One farmer fought the fire to protect his buildings, and a force

of 10 men started out from Newfoundland, but seeing that their woods were safe, returned home before reaching the fire. Average loss, $5.50 per acre; total, $6,600.

50. May 7th, 1903. One mile south of Charlottesburg, on the road from Charlottesburg to Split Rock pond, a fire, cause unknown, burned 950 acres, mainly oak and chestnut. Four hundred acres were from 2 to 20 years' growth; 200 acres from 20 to 40 years; 200 acres from 40 to 50 years; the balance being old oak of great value. Forty per cent. of the total growth were killed. The fire was fought by backfiring, but not until after it had been burning three days. Average loss, $8.00 per acre; total, $7,600.00.

OCEAN COUNTY.

51. During the last week in April, a fire, started by school children picking wild flowers, occurred one and one-half miles north of New Prospect, which burned 400 acres, mainly of pine, from 8 to 19 years old. Seventy-five per cent. of the timber were killed, no effort being made to extinguish the fire. Average loss, $1.75 per acre; total, $700.00.

52. May, 1903. Southwest of Burkville, smokers started a fire, which burned 800 acres of pine and some oak of good growth, from 10 to 25 years old. Ninety per cent. of the pine was killed, and the oak was entirely killed. The fire was fought unsuccessfully by backfiring. Average loss, $2.25 per acre; total, $1,800 dollars.

53. May, 1903. A charcoal burner started a fire northeast of Cassville, which burned 2,000 acres of pine and oak, averaging 15 years old growth. The timber was mostly all killed. No effort was made to extinguish the fire. Average loss, $2.00 per acre; total, $4,000.00.

54. April 30th, 1903. East of Whitings, near Keswick Colony, a fire, started by smokers, swept over a territory 5 by 10 miles, burning 5,500 acres of pine from 10 to 30 years old, and killing all the young pines. Pines over 25 years old were injured and the oaks were killed. Two cedar swamps with cedar 18 and 10 years were also killed. Some parts of this area had not been burned in

30 years. The fire was fought at Whitings and Lakehurst. The first day, with the wind westerly, the fire covered five miles, the second day, with the wind easterly, it covered five more miles, coming within one mile of Lakehurst. Average loss, $2.00 per acre; total, $11,000.

55. March 27th, 1903. One and one-half miles southwest of Whitings, between Whitings and Wheatland, a fire, caused by a locomotive, burned 250 acres of pine and oak from 8 to 25 years old. The oaks were killed, as were also 60 per cent. of the pines. The fire was fought by railroad section men with success. Average loss, $2.00 per acre; total, $500.00.

56. April 18th, 1903. Near Wheatland, sparks from a locomotive set fire to 75 acres of poor pine and oak, which were killed. No effort was made to extinguish the fire. Average loss, $0.75 per acre; total, $56.00.

57. April 24th, 1903. One-half mile south of Forked River, burning brush set fire to and destroyed two acres of 12 year old oaks. One house was also burned. No effort was made to fight the fire. Total loss, $10.00.

58. April 24th, 1903. At "Wells Mills," southwest of Forked River, a fire, caused by burning brush, burned and killed 50 acres of pine and oak averaging 18 years old. No efforts were made to extinguish the fire. Average loss, $2.50 per acre; total, $125.00.

59. April 29th, 1903. At the north edge of Barnegat, locomotive sparks set fire to six acres of pine, oak and maple of good growth, 30 years old. The timber was killed. The fire was fought by railroad men soon after it started. Average loss, $5.00 per acre; total, $30.00.

60. May 2d, 1903. A fire occurred at Tuckerton, west of Tuckerton mill-branch, caused by burning brush. It covered 40 acres of pine, oak and some cedar from 6 to 20 years' growth, which was killed. This tract was slightly burned in 1894. The fire was fought with shovel and sand. Total damage, $30.00.

PASSAIC COUNTY.

61. May, 1903. Boys playing with matches started a fire three-fourths of a mile east of Charlottesburg station on the road

to Butler. Three hundred acres of very thrifty oak and chestnut, 30 years old, were badly injured. The fire was fought with brush. Average loss, $1.50 per acre; total, $450.00.

62. May, 1903. A fire, caused by a locomotive, started between Oak Ridge and Stockholm and extended toward Dunker pond. It burned and killed 70 acres of chestnut and oak of five years' growth. No efforts were made to extinguish it. Average loss, $0.75; total, $52.00.

63. May, 1903. Between Monks and Hewitt, sparks from a locomotive set fire to 15 acres of 25 year old chestnut and oak, killing 80 per cent. No effort was made to extinguish the fire. Average loss, $4.00 per acre; total, $60.00.

64. April, 1903. South of Hewitt, a locomotive started a fire which burned 20 acres of chestnut and oak, 30 years old. Sixty per cent. were killed and the balance badly injured. No effort was made to fight the fire. Average loss, $3.50 per acre; total, $70.00.

65. May 3d, 1903. Southeast of Negro pond, tramps set fire to 700 acres of chestnut and oak from 10 to 70 years old, killing 40 per cent. One hundred acres of good chestnut 55 years old were also killed. Some effort was made to extinguish the fire, but without success. Average loss, $4.00 per acre; total, $2,800.

SOMERSET COUNTY.

66. March, 1903. Two and one-half miles northeast of Somerville, boys set fire to 120 acres of oak and chestnut, 10 years old, which were badly injured. A grove of red cedar was killed. The fire was beaten out with young cedar trees. Average loss, $1.50 per acre; total, $180.00.

SALEM COUNTY.

67. April 23d, 1903. One-half a mile east of Elmer, a fire, started by burning brush, burned 1,600 acres. One thousand acres of young oak and chestnut of promising growth, 2 to 12 years old, were killed, and 600 acres badly injured. Two hun-

dred cords of cord wood worth $2.00 per cord were burned in the woods. The fire was fought by backfiring. Loss on cord wood, $400. Average loss per acre, on standing timber, $3.50; total, $5,600.

68. April 30th, 1903. Between Elmer and Palantine station, a fire, due to a locomotive, burned 40 acres of oak and chestnut from 8 to 38 years old. The young growth was killed, and the older trees injured. This tract was burned in 1865. No efforts were made to extinguish the fire. Average loss, $7.00 per acre; total, $280.

69. May 3d, 1903. Two miles southeast of Alloway, at "Pine Branch," a fire, started by children picking flowers, burned over 300 acres. One hundred and fifty acres of very promising oak and chestnut, 25 years old, and 150 acres of brush land were injured. No effort was made to fight the fire, it being extinguished by rain on May 4th. Average loss, $5.00 on 150 acres; total, $750.

70. May 10th, 1903. Near Alloway, 100 acres of promising oak and chestnut, 20 years old, were injured by a fire started by children picking flowers. No effort was made to extinguish the fire. Average loss, $4.00 per acre; total, $400.

SUSSEX COUNTY.

71. April, 1903. A fire, lasting 15 days, caused by burning brush, burned over 5,000 acres in Montague, Sandyston and Wantage townships. The timber was mainly oak and chestnut, 20 to 30 years old. A quantity of fences was also destroyed. A little part was burned in 1894 and 1902. The fire was fought by a force of men who worked three days and three nights carrying water from Lake Mashipacong. They succeeded in saving buildings. Near Coleville it was fought by backfiring with success. Average loss, $2.00 per acre; total, $10,000.

72. May, 1903. Near Franklin Furnace, a fire, cause unknown, burned 100 acres of oak and chestnut of good growth, 35 years old. Fifty per cent. were killed. Average loss, $4.75 per acre; total, $475.

73. May, 1903. Sparks from a locomotive started a fire near Losee pond, south of the railroad, which burned over 800 acres. Two hundred and seventy-five acres of oak and chestnut, 15 years old, were killed; of 300 acres of oak and chestnut, 25 years old, 75 per cent. were killed; 50 acres brush land and 100 acres old oak and chestnut, 60 to 100 years old, were injured. Seventy-five acres were barren land. No efforts were made to extinguish the fire. Average loss, $6.00; total, $4,800.

74. May, 1903. Near Two Bridges, a fire, due to a locomotive, burned 700 acres, mainly oak and chestnut, 15 to 35 years' growth, 35 per cent. of which were killed. The fire was fought by railroad section men. Average loss, $2.00 per acre; total, $1,400.

75. During the first week in May, a fire, started by a locomotive, occurred north of Ford on both sides of the county line and both sides of the railroad, burning into Morris county. It burned 1,200 acres of oak and chestnut 5 to 15 years old, 95 per cent. of the growth being killed. This area was never burned over before this. No efforts were made to put the fire out. Average loss, $8.00 per acre; total, $9,600.

76. May, 1903. A fire, of unknown origin, started at White Hall, south of Andover, burning toward Waterloo. Seven hundred and fifty acres of chestnut and oak, averaging 25 years old, were burned, killing 60 per cent. Very little effort was made to extinguish the fire. Average loss, $3.00 per acre; total, $2,250.

77. May, 1903. Near Sparta Junction, a fire, due to a locomotive, occurred in the early part of May. Two hundred acres of promising oak and chestnut, with an average growth of 25 years, were burned, of which 80 per cent. were killed. No fire had ever occurred on the tract before, and no effort was made to extinguish this. Average loss, $7.00 per acre; total, $1,400.

78. May, 1903. Near Morris pond, smokers set fire to 150 acres of chestnut and oak, 15 years old. Eighty per cent. were killed, no effort being made to extinguish it. Average loss, $2.00 per acre; total, $300.

UNION COUNTY.

79. May, 1903. During the latter part of May, tramps started a fire west of Linden, on Morses creek, which burned three acres of scrubby oak of but little value. The fire burned itself out. Average loss, $0.50 per acre; total, $1.50.

CAUSES OF FIRES.

Railroad locomotives,	26
Farmers burning brush, grass, clearing land and burning turf on cranberry bogs,	21
Unknown,	8
Smokers,	7
Children picking wild flowers and boys playing with matches,	6
Tramps,	4
Incendiary,	3
Feeble-minded person,	1
Charcoal burners,	1
Campers,	1
Accidental,	1

A summary by counties is as follows:

Atlantic,	11	fires,	24,700	acres	burned	over;	damage,	$75,205	00
Burlington,	7	"	21,925	"	"	"	"	107,394	00
Cumberland,	9	"	8,265	"	"	"	"	17,342	00
Cape May,	4	"	2,720	"	"	"	"	13,985	00
Camden,	1*	"	7	"	"	"	"	420	00
Gloucester,	6	"	1,055	"	"	"	"	4,104	00
Monmouth,	2	"	558	"	"	"	"	3,854	00
Morris,	10†	"	4,525	"	"	"	"	23,921	00
Ocean,	10	"	9,123	"	"	"	"	18,251	00
Passaic,	5	"	1,105	"	"	"	"	3,432	00
Somerset,	1	"	120	"	"	"	"	180	00
Salem,	4	"	2,040	"	"	"	"	7,430	00
Sussex,	8	"	8,900	"	"	"	"	30,225	00
Union,	1	"	3	"	"	"	"	1	50
	79	"	85,046	"	"	"	"	$305,744	50

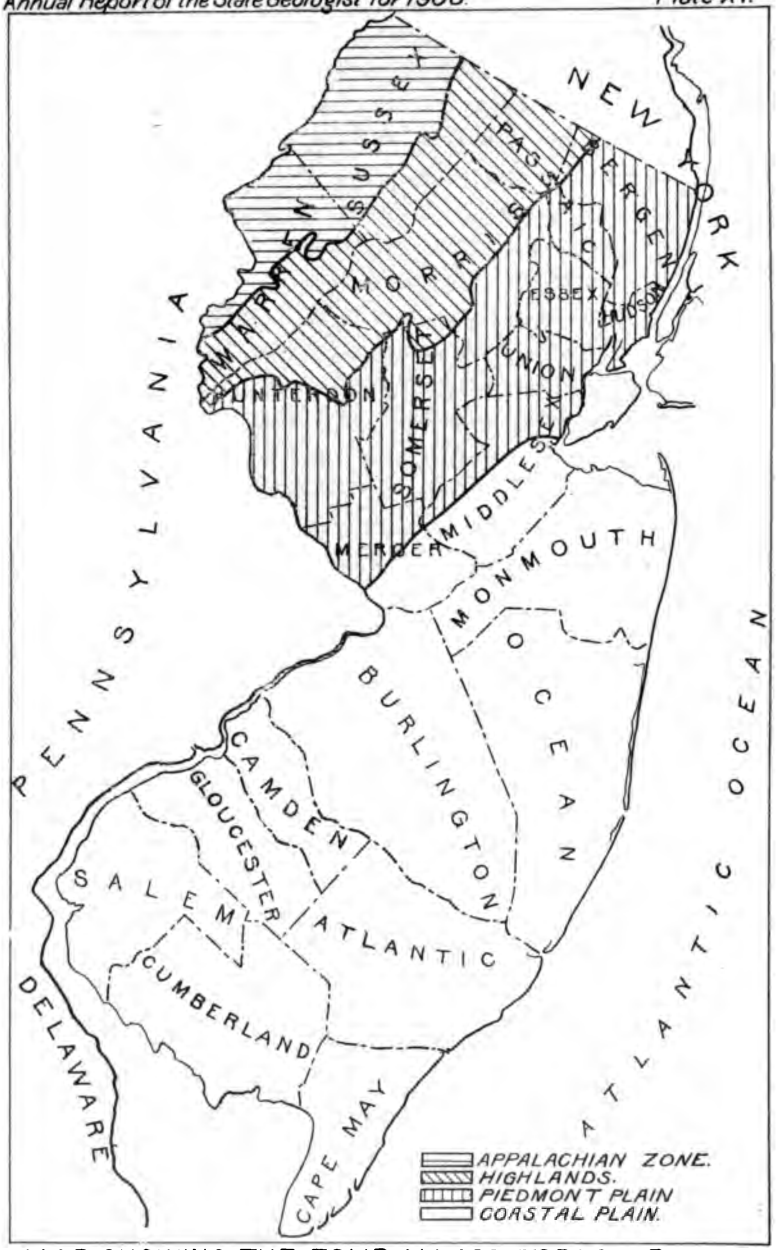
* One of the Burlington county fires started in Camden county.

† One of the Sussex county fires burned also in Morris county.

PART IV.

Underground Waters of New Jersey. Wells Drilled in 1903.

By G. N. KNAPP.



MAP SHOWING THE FOUR MAJOR TOPOGRAPHICAL DIVISIONS OF NEW JERSEY.

Underground Waters of New Jersey. Wells Drilled in 1903.

BY G. N. KNAPP.

Artesian and Other Deeply Penetrating Waters of New Jersey.

New Jersey has been divided into four provinces or zones on the basis of its physiographic features.* These provinces are indicated on the accompanying sketch map, Plate XI, and are designated: 1°, the Appalachian; 2°, the Crystalline Highlands, 3,° the Piedmont, and 4°, the Coastal plain. The topographic features of these several provinces, by virtue of which they differ the one from the other, are in large measure simply the outward manifestation of internal characters, structural and lithological, inherent in the terranes of the different provinces, that have been given expression by subaerial and stream degradation.

As might be anticipated, the underground or deeply penetrating waters of the State sustain relations differing with the different provinces and more or less characteristic of them. Rocks so different in structure and lithological character as to give rise to topographic features so pronounced and characteristic as are those of the several provinces, might be expected to profoundly affect the disposition of underground water. This is, in fact, found to be true, and we accept this subdivision of the State as the one best adapted to a general discussion of the deep waters.

* N. J. Geol. Survey, Final Report, Vol. IV, Physical Geog., 1895.

THE APPALACHIAN PROVINCE.*

The Appalachian province, or zone, is the northern extension of the great Appalachian mountain sytem as it occurs in New Jersey. It is essentially coincident with the great Kittatinny valley and Kittatinny mountain.

It consists of limestone, slates, conglomerates, sandstones and quartzites, strongly infolded in anticlines and synclines whose axes run northeast and southwest. These primary folds have, subsequent to their development, been more or less faulted and cut by dikes and late intrusions. The whole has been profoundly eroded; plains of degradation have developed, truncating the old folds, and later broad deep valleys developed parallel to the main axes of the folds. In these broad valleys we now have the softer beds, such as limestones and shales, standing at various angles between vertical and horizontal, and dipping in discordant directions. The ridges, or mountains, inclosing these valleys consist of the harder beds, viz., conglomerates, quartzites, slates and sandstones, rising more or less abruptly 500 or 700 feet above the valleys. The beds themselves stand at various angles, commonly approaching verticality.

The various beds of the Appalachian zone have in large measure lost through induration what porosity they may once have had. The sandstones have become quartzites more or less dense; the conglomerates have suffered a like modification, reducing the porosity to a minimum, and the other rocks have suffered similar modification tending to increase the density. The rocks have, however, been fractured at various times, so that joints occur more or less abundantly through the beds, admitting water to unknown depths; solution also has developed cavities and more or less definite underground courses through the limestones.

The rocks of the Appalachian province are therefore relatively impervious, and do not carry a large volume of water. The water that does penetrate deeply does so by virtue of secondary

* Statements regarding the underground waters of the Appalachian, Crystalline Highlands, and Piedmont provinces are compiled from data in the previous reports of the Survey.

structures and other modifications that do not stand in close relation to the primary structure.

It transpires, therefore, that the structure, which is regular enough to be worked out with considerable definiteness, is not of so much service in locating successful wells as might be expected. The water seems capricious in its occurrence. The data available, however, show but few deep wells in this province, too few to be made the basis of final conclusion, so that the great Kittatinny valley has yet to be thoroughly tested for its available deep-water supply.

THE CRYSTALLINE HIGHLANDS PROVINCE.

The Crystalline Highlands, as the name suggests, consists more largely of crystalline rocks, granites, schists and gneisses. The great structural lines of the region run northeast and southwest, like those of the Appalachian zone, but this region has been subject to more profound metamorphism; the beds have been repeatedly broken and faulted at widely separated time intervals. Intrusive rocks have been injected as dikes and bosses, at different times, and according to different systems. Secondary structures have very generally destroyed or replaced the original ones; and along with this have gone replacement and interchange in the mineral constitution until it frequently is difficult to tell whether the rock is metamorphosed sedimentary or a metamorphosed granite.

In the Crystalline Highlands, therefore, the structure is too complex and too indefinite to aid one in a practical way in predicting wells, and the formations contain no well-defined porous beds that in a true sense can be called water-bearing in contradistinction to others adjacent. The rocks, however, as a whole, are more generally permeated by water than in the Appalachian zone, so that borings made indiscriminately give a larger percentage of satisfactory wells in the former than in the latter region. We know from the numerous iron mines scattered through the Highland region that the permeation of these old crystallines by water, while very general, is by no means uniform; for some mines encounter large volumes of water greatly to their detriment,

whereas others are comparatively dry. The relation, if any, that exists between the local rock structure or the depth of the mine and the volume of water encountered is not apparent.

There are in the Highland province some notable exceptions to the structure as above outlined; such, for instance, as the Green Pond mountain belt, where the structure is analogous to the infolding of the Appalachian zone. In these exceptional areas the deep waters behave much as they do in the Kittatinny region.

The numerous streams, as yet not polluted, afford an abundance of excellent water. This, together with the cost of drilling in such hard rock, i. e., five to ten dollars per foot, has heretofore limited the number of deep wells.

This province, however, is being invaded by suburban homes and country residences, and we may look forward in the near future to more deep wells than the past has afforded.

THE PIEDMONT PROVINCE.

The Piedmont province is essentially the area of the Newark or red sandstone system. The Newark consists of three series of beds, which, from base upwards, are: The Stockton, the Lockatong and the Brunswick.

The Stockton consists of light-colored sandstones and conglomerates, more or less arkose, interbedded with a few red shales. It is the most permeable series of the Newark system.

The Lockatong consists chiefly of flagstones and argillites, and is relatively impervious.

The Brunswick series consists chiefly of shales, but includes also many beds of sandstones. It is less permeable than the Stockton.

The Newark system is traversed by a number of irregular faults, whose throw in two cases is nearly sufficient to repeat the entire system. The prevailing dip of the beds is west and northwest but accompanying the faulting was more or less local warping and tilting that gave the beds many local variations in dip and strike. The structure is further complicated by a system

of volcanic intrusive sheets and trap dikes that cut across the bedding at various angles.

While our knowledge of the Newark beds is not sufficiently detailed to enable us to forecast the chances of obtaining artesian water at any given point, or even to assure us that well-defined water-bearing horizons exist, yet experience shows that a moderate supply of water can usually be obtained anywhere in these beds at depths of a few hundred feet at most. The fact that the rocks of the Newark system are thoroughly cut up by several systems of deeply penetrating joints, whose planes approach the vertical and intersect at various angles, and the further fact that in many wells the amount of water increases gradually with depth of the boring, apparently indicates that the water is present more largely in these joints and fissures than in any well-defined porous water-bearing beds. This inference is supported by observations made in several long tunnels in the red shale, where frequent streams of water were found following vertical fissures, while the bedding planes were nearly dry and no porous layers were observed.

Although the record of deep borings in the Newark rocks does not indicate the presence of copious supplies of water, yet in a few localities in the Piedmont belt conditions are such, owing to the glacial deposits of sand, gravel and bowlder clay, that flowing wells of great volume have been found. These conditions seem most commonly present in the basin of the glacial Lake Passaic, particularly where beds of open gravel beneath impervious layers of clay afford the requisite conditions for the accumulation of large supplies of water under considerable pressure. From the irregular distribution of the glacial drift, and the extremely local character of these deposits, no adequate forecasts can be made as to the occurrence of these copious water-supplies, but they may be looked for wherever the topography is such as to suggest the recurrence of a basin-shaped depression in the rock surface and a considerable accumulation of glacial drift.

Of the three provinces thus far considered the last, or Piedmont, carries vastly more deep water than either of the others. Moreover, it is found in rocks that are drilled with comparative ease. Furthermore, the Piedmont is by virtue of its geographical

position the most important of the three, since it includes what is and what always will be, the most densely populated part of the State, in which the water supply, accordingly, always will be a paramount question.

THE COASTAL PLAIN PROVINCE.

The Coastal plain differs from the three northern provinces in nearly every essential feature.

First, it includes an area greater than the combined area of the other three provinces.

Second, there are no mountains; the maximum relief is less than 400 feet. As compared with the other provinces, it is flat.

Third, the structure is of the simplest sort, consisting of a succession of beds, lying one upon the other, in a simple monocline, dipping seaward; the uppermost or youngest bed lying furthest southeast, and each successively older and lower bed reaching a little farther northwest.

The structure is indicated diagrammatically in Plate XII. (In the delineation of the salient features of the general structure, Plate XII is, to the best of our knowledge, true to the facts; subject, of course, to the accompanying explanation. In the delineation of the beds by mathematically straight lines, the figure is, of course, entirely diagrammatic.)

Fourth, there have been no faults or fold of sufficient magnitude to appreciably affect the general structure.

Fifth, the beds are unconsolidated—sands, clays, marls and gravels, and lie in essentially the same position in which they were deposited.

Sixth, the terranes have not suffered any metamorphism that has appreciably affected their permeability to water.

The Coastal plain province falls into two great natural divisions or subprovinces, viz., the Cretaceous and the Tertiary.

The Cretaceous occupies a relatively narrow belt across the State, indicated diagrammatically in Plate XII by beds 0 to 10.

The Tertiary includes the remainder of the province corresponding to beds 11 and 12, Plate XII.

The Cretaceous has three major divisions, which from base upward are the Raritan, the Clay Marl series, and the Marl series. (The Clay Marl series corresponds approximately, but not exactly, to the "Matawan" of the later nomenclature. The Marl series includes approximately, but not exactly, the "Monmouth," "Rancocas" and "Manasquan" of later nomenclature.)

The Raritan, though carrying important water beds at different stratigraphic horizons, does not admit of subdivision.

The Clay Marl series, on the other hand, is readily subdivided into five beds, corresponding to beds 1 to 5 in Plate XII.

Beds 1 and 2 are an impervious marl and clay, and serve as a cover-bed to the Raritan water-bearing sands. No. 3 is a sand-bed, which is 100 feet thick to the northeast, where it is an important water horizon; to the southwest it pinches out entirely and disappears along the strike. Bed No. 4 is an impervious marl and clay, a cover-bed to No. 3, Bed No. 5 is a sand bed 100 feet thick to the southwest, where it is an important water horizon. To the northeast it becomes less important, partly by reason of its decrease in thickness in that direction, and partly by a decrease in permeability.

The Marl series, like the Clay Marl series, is readily subdivided into five beds, corresponding to beds 6 to 10 in Plate XII.

Bed No. 6 corresponds to the Lower Marl (approximately the "Navesink"); bed No. 7 is the Red Sand (Red Bank). It is an important water horizon to the northeast, where it is a sand bed 100 feet thick, but to the southwest it pinches out like No. 3, and disappears along the strike. Bed No. 8 is the lower portion of the old Middle Marl bed, the marl proper. (It constitutes a part, but not all of the "Sewell.") Bed No. 9 is the lime and "yellow" sand; the upper part of the old Middle Marl bed (including the "Vincentown" and more). This is a very important water horizon all across the State. Bed No. 10 is the Upper Marl, a part of which is Eocene. It is the impervious cover to bed No. 10.

The second subprovince of the Coastal plain, the Tertiary, is divided into two formations, the Kirkwood (Miocene), and the Cohansey (Pliocene?) corresponding respectively to beds 11 and 12 of Plate XII.

Bed No. 11 is the Kirkwood. It carries water-bearing sands at several different stratigraphic horizons. It is an important source of water at Atlantic City and southward on the beaches. Bed No. 12 is the Cohansey formation. It carries water at several different stratigraphic horizons, and rivals the Kirkwood as a source of artesian water along the beaches.

The structure of the Coastal plain is extremely simple. The outcrop of the beds is known in great detail. The dip is known, or is readily determinable, and our topographic atlas gives us the altitude at all points. Still the predicting of artesian water at any given point is not the simple mathematical proposition that Plate XII might suggest.

The chief difficulties experienced in predicting wells are two. First, the thickening of the beds down the dip, seaward, has not been worked out in detail for individual beds. Second, the permeability of the beds is a variable factor whose exact value is yet to be worked out.

Investigations now in progress are expected to contribute much toward the solution of these difficulties.

PROVINCES.

	Appalachian.	*Crystalline Highlands.*	*Piedmont.*	***Coastal Plain.***
Area in Sq. Miles,	547	945	1,463	**5,099**
Approximate Population,	24,201	76,029	1,222,586	**495,072**
Average No. of People per Sq. Mile,	44.2	80.4	836.3	**97.7**
Maximum Density of Pop. per Sq. Mi., per Twps.,	1,590	8,475	22,560	**14,492**
Minimum Density of Pop. per Sq. Mi., per Twps.,	23	26	37	**6**
Records of Wells in	23	31	547	**998**
Average No. of Sq. Miles to each well,	24	30	26	**5**

The accompanying table brings into prominence many important relations and suggests many more that space forbids our discussing. A word explanatory of the table will, however, be allowable.

First. It will be noticed that of the 1,600 wells catalogued in the Survey office, 1,000 are found in the Coastal plain province;

they range in depth from 50 to 2,300 feet; probably 90 per cent. of these are of the true artesian type, that is, they draw their water from a bed whose catchment area is remote from the well, and the water in the wells rises quite to the surface, and frequently above the surface, giving flowing wells.

Of the 550 in the Piedmont plain comparatively few are of the true artesian type; they range in depth from 50 to 600 feet; some of them yield large volumes of water; a few of them flow, but, as before suggested, those in bedrock probably draw their supply more largely from the joints and the secondary structures than from the water that permeates the true bedding, and the most copious are in the glacial drift.

Of the 50 or 60 wells in the two northern provinces, with possibly a few exceptions, none are truly artesian: they are simply deep reservoir-like holes into which water is percolating from innumerable joints and fissures at all horizons from top to bottom. While the gathering ground of such waters may be remote from the wells they belong in a different class from those of the Coastal plain. It will be remembered that the wells here catalogued are the ones of which we have records, but not the actual total number of wells in these provinces. There are undoubtedly many wells doing service of which we have no record.

The Appalachian and Crystalline provinces are relatively sparsely settled; springs abound, and mountain streams, proverbially wholesome, and, as yet, unpolluted, are numerous and well distributed; so that the demand for deep wells is not a pressing one.

The Piedmont area includes two fairly distinct subprovinces. First, the northeast part of the area, in vicinity of Essex and Hudson counties, is occupied by numerous cities large and small, which are in a large measure manufacturing centers.

Second. In the northwest portion, in vicinity of Somerset county, agriculture is the dominant interest. The former of these subprovinces includes about one-fifth of the area of the Piedmont, and claims about nine-tenths of the population, while the remaining one-tenth of the population is scattered over the remaining four-fifths of the province to the southwest.

Of the 550 wells in the Piedmont more than five hundred occur in the densely populated region to the northeast; and, for the most part, subserve the interests of manufacture.

In the Coastal plain province we find the densely populated districts distributed around the periphery of the province, the interior being more sparsely settled. The distribution of the artesian wells stand in a fairly definite relation to the density of the population.

Along the beaches are many thriving towns and cities whose function is almost wholly one of ministering to those in quest of health, recreation and pleasure. These communities, while not absolutely dependent on artesian wells for their water supply, find it the most practicable source, and hence we find a large percentage of the wells along the coast.

The north and northwest border of this province, which is approximately the outcrop of the Cretaceous terranes, finds its interests divided between agriculture and manufacturing. The artesian wells, which are abundant in this region, are less deep than those along the coast, and accordingly less expensive. They are found ministering to both the manufacturing and the agricultural interests.

The distribution of the artesian wells is determined, first, by the availability of the water; second, by the density of the population; and third, by the character of the population.

New Deep Wells in 1903.

On the following pages a record of the new wells bored during the year 1903 and reported to the Survey are given. This record is not so detailed as in former years, owing to the sudden death early in the year of Lewis Woolman, who had with painstaking care collected the data for previous reports. The Survey has not been able in any case to verify the records, nor to examine samples, but publishes the data substantially as reported by the welldrillers.

WELLS DRILLED IN 1903.

Locality.	Owner.	Diam.	Record.		Total Depth.	Reported by	Remarks.
Allamuchy, ...	Mrs. W. K. Vanderbilt,	6 in.,	Earth, ...	16 ft.			
			Gray mountain rock, hard, ...	139 ft.	155 feet, ...	Stotthoff Bros., ...	14 gallons per minute.
Alpha, ...	Alpha Portland Cement Co., ...	10 in.,	Cement rock, ...	335 ft.			
			Limestone, ...	20 ft.	355 feet, ...	Stotthoff Bros., ...	Well started in bottom of quarry. 150 gallons per minute.
Anglesea, ...	Arctic Ice Co., ...	4½ in.,	....		330 feet, ...	Uriah White Estate, ...	30 feet of 3-inch strainer. Pumping capacity, over 200 gallons per minute.
Atlantic City, ...	Fairbairn & Williams, The Strand, ...	6 in.,	....		826 feet, ...	Uriah White Estate, ...	Finished with 50 feet of strainer. Pumping capacity, 100 gallons per minute.
Belmont, ...	Botany Worsted Co., ..	6 in.,	Earth and gravel, ...	54 ft.			
			Red sandstone rock, .	19 ft.	83 feet, ...	Stotthoff Bros., ...	3 gallons per minute.
Belmont, ...	M. Macher, ...	6 in.,	Earth and gravel, ...	38 ft.			
			Red sandstone, ...	25 ft.	63 feet, ...	Stotthoff Bros., ...	12 gallons per minute. Flowing well.
Bernardsville, ...	J. A. Bensel, ...	6 in.,	Earth, ...	8 ft.			
			Granite rock, hard, ..	78 ft.	86 feet, ...	Stotthoff Bros., ...	100 gallons per minute at 20 feet from the surface.
Bordentown, ...	French Gelatine Co., ...	8 in.,	Light brown sand, ...	11 ft.			
			Fine gray sand, ...	5 ft.			
			Yellow sand, ...	5 ft.			
			Gray quicksand, ...	8 ft.			
			Yellow quicksand, ..	6 ft.			
			Coarse yellow sand and water, ...	22 ft.			
			Blue clay, ...	6 ft.			
			Red clay, ...	10 ft.	73 feet. ...	Stotthoff Bros., ...	Draws water from the Raritan beds. 55 gallons per minute.

Locality.	Owner.	Diam.	Record.		Total Depth.	Reported by	Remarks.
Bridgeton,	Bridgeton Water Co.,	8 in.,			990 feet,	Thos. B. Harper,	Well finally screened off at 225 ft. Water rose to within 2 feet of surface.
Bridgeton,	Bridgeton Water Co.,	8 in.,			88 feet,	Thos. B. Harper,	Water rose to within 2 feet of surface.
Bridgeton,	Bridgeton Water Co.,	8 in.,			90 feet,	Thos. B. Harper,	Water rose to within 2 feet of surface.
Clementon, 500 ft. south of R. R. crossing,	Fred. McCann,	3 in.,	Soil,	1 ft.			
			Light colored sand,	4 ft.			
			Loose gravel,	2 ft.			
			Fine compact sand,	4 ft.			
			Yellow quicksand, (Poor water.)	12 ft.			
			Black mud,	28 ft.			
			Dark brown sandy clay,	30 ft.			
			Black clay,	12 ft.			
			Sand, some shells,	10 ft.			
			"Limestone,"	2 ft.			
					105 feet,	Fred. E. McCann,	Good water found beneath the "limestone." Rises to within 22 feet of surface. Probably from upper part of the Vincentown lime-sand.
Dumont,	Mrs. Van Antwerp,	6 in.,	Earth and gravel,	24 ft.			
			Red sandstone rock,	126 ft.			
					150 feet,	Stotthoff Bros.,	20 gallons per minute.
East Rutherford,	Fuchs & Lang Mfg. Co.	8 in.,	Glacial drift,	57 ft.		W. W. Christie,	Not completed.

Locality.	Owner.	Diam.	Record.		Total Depth.	Reported by	Remarks.
Easton, Pa.,	Easton Dairy Co.,	6 in.,	Sand and gravel, Limestone rock,	59 ft. 87 ft.	146 feet,	Stotthoff Bros.,	116 gallons per minute.
Haledon,	Theo. Leonhard,	6 in.,			120 feet,	W. W. Christie,	Small flow.
Laurel Springs, Park Ave.,	Chas. Mund,	3 in.,	Soil, Fine sand, Very fine sand, Stiff, dark sandy clay, Black mud, Black marly sand, Compact gray sand (some shells), Lime rock,	1 ft. 4 ft. 2½ ft. 6 ft. 6 ft. 10 ft. 1 ft. 3½ ft.	34 feet,	Fred. E. McCann,	Water found below the "lime rock" in a dark grey sand, probably in the Vincentown limesand formation.
Laurel Springs, Park Ave.,	Chas. Mund,	3 in.,	Soil, Fine sand, Coarse sand, Yellow gravel,	1 ft. 4 ft. 2 ft. 10 ft.	17 feet,	Fred. E. McCann,	A surface water filtered through the sand and gravel.
Linden,	Walter Luchen,	5 in.,	Glacial drift, Red shale,	30 ft. 11 ft.	41 feet,	Frank T. Cladek,	20 gallons per minute.
Linden, Wood Av.	C. H. & John Winans,	6 in.,	No. 1 Glacial drift, Red shale,	16 ft. 184 ft.	200 feet,	Frank T. Cladek,	These two wells each produced on three weeks' test, night and day pumping, 1,080,000 gallons per 24 hours.
		6 in.,	No. 2 Glacial drift and red shale, 150 feet from No. 1,		146 feet,		

Locality.	Owner.	Diam.	Record.		Total Depth.	Reported by	Remarks.
Linden,	P. R. R. Station,	5 in.,	Glacial drift, Red shale,	32 ft. 90 ft.	122 feet,	Frank T. Cladek,	21 gallons per minute.
Manasquan,	Manasquan Water Works,	6 in.,			120 feet,	Uriah White Estate,	10 feet of 4½-inch strainer. Flowed 20 gallons per minute. Pumping capacity, 200 gals. per minute. Encountered rotten stone in well Nos. 2 and 3. Water was analyzed from these wells and was reported pure but it had a slight odor.
Manasquan,	Manasquan Water Works,	4½ in.,			47 feet,	Uriah White Estate,	Finished with 21 feet of 4½-inch strainer. Pumping capacity, 37 gallons per minute.
Manasquan,	Manasquan Water Works,	6 in.,			130 feet,	Uriah White Estate,	20 feet of 4½-inch strainer. Flowed 30 gallons per minute. Pumping capacity, over 200 gallons per minute.
Monroe,	Jacob M. Demerest,	6 in.,	Earth and gravel, Limestone,	16 ft. 72 ft.	88 feet,	Stotthoff Bros.,	6 gallons per minute. Water stands within 13 feet of surface.
Mulford,	C. C. Cox,	6 in.,	Earth, Limestone,	9 ft. 50 ft.	59 feet,	Stotthoff Bros.,	15 gals. per minute. Water stands 14 feet from surface.
New Orange,	H. S. Kerbaugh,	8 in.,	Earth, sand and gravel, Red shale,	45 ft. 161 ft.	206 feet,	Stotthoff Bros.,	60 gals. per minute. Water stands 14 feet from surface.

Locality.	Owner.	Diam.	Record.		Total Depth.	Reported by	Remarks.
Ocean City,	Water Company,				812 feet,	Thos. B. Harper,	60 gallons per minute.
Passaic,	Botany Worsted Co.,	10 in.,	Sand and gravel, Red sandstone,	86 ft. 114 ft.	200 feet,	Stotthoff Bros.,	135 gallons per minute.
Passaic,	Botany Worsted Co.,	10 in.,	Sand and gravel, Red sandstone rock,	86 ft. 164 ft.	250 feet,	Stotthoff Bros.,	60 gallons per minute.
Paterson, Ellison and Main,	Quackenbush & Co.,	8 in.,			88 feet,	W. W. Christie,	Good flow.
Perth Amboy,	E. W. Barnes,	6 in.,	Yellow sand, Red hardpan, Yellow sand and water, Red clay below,	18 ft. 55 ft. 17 ft. 3 ft.	93 feet,	Stotthoff Bros.,	45 gallons per minute.
Pinkneyville,	C. C. Cox,	6 in.,	Deep brown sand and gravel entire distance,		73 feet,	Stotthoff Bros.,	12 gals. per minute. Water stands 32 feet from surface.
Pleasantville,	Atlantic City Water Board,		Eleven wells from 323 ft. to 99 ft.,		100 $\pm$ feet,	Thos. B. Harper,	Each finished with a 20-ft. screen. Together yield 4,000,000 gallons per diem.
Princeton,	Mr. Schemmer,		Dirt, Rock,	6 ft. 284 ft.	290 feet,	Thos. B. Harper,	60 gallons per minute.
Princeton,	University,		Dirt, Rock,	14 ft. 320 ft.	334 feet,	Thos. B. Harper,	125 gallons per minute.
Rahway, Scott Ave.,	J. Deickoft,	6 in.,	Quicksand, Red shale,	28 ft. 14 ft.	42 feet,	Frank T. Cladek,	Elevation A. T., 26 feet; 5 gallons per minute.
Rahway, Hazlewood Ave.,	Mr. Englehardt,	6 in.,	Sand and gravel, Red shale,	30 ft. 120 ft.	150 feet,	Frank T. Cladek,	Plenty of water at 30 feet. Elevation, 40 A. T.

Locality.	Owner.	Diam.	Record.		Total Depth.	Reported by	Remarks.
Rahway, Milton Ave.,	Edw. Savage,	6 in.,	Sand and "hardpan," Red shale,	35 ft. 134 ft.	169 feet,	Frank T. Cladek,	20 gallons per minute at 35 feet in sand; 8 gallons per minute at 169 feet in rock.
Rahway, Rahway Ave.,	Geo. W. Bowe,	6 in.,	Glacial drift, Red shale,	14 ft. 186 ft.	200 feet,	Frank T. Cladek,	8 gallons per minute at 200 feet. Explosion of dynamite did not improve the flow.
Rahway Port,	W. H. Maze,	5 in.,	Glacial drift, Red shale,	34 ft. 26 ft.	60 feet,	Frank T. Cladek,	Elevation, 30 A. T. 20 gallons per minute.
Roselle, Linden St.	W. H. Weldon & Son,	5 in.,	Fine sand, Red shale,	76 ft. 5 ft.	81 feet,	Frank T. Cladek,	20 gallons per minute at 20 feet.
Roselle, near Dark lane,	J. Nestor,	6 in.,	Glacial drift, Bed rock,	9 ft. 23 ft.	32 feet,	Frank T. Cladek,	10 gallons per minute.
Skillman,	N. J. State Village for Epileptics,	6 in.,	Earth, Red shale,	3 ft. 211 ft.	214 feet,	Stotthoff Bros.,	14 gallons per minute.
Trenton,	J. A. H. Delp,	6 in.,	Earth and gravel, Red sandstone,	18 ft. 18 ft.	36 feet,	Stotthoff Bros.,	15 gallons per minute.
West Portal,	Farmers' Dairy Dispatch Co.,	8 in.,	Earth and bowlders, Limestone,	52 ft. 8 ft.	60 feet,	Stotthoff Bros.,	28 gallons per minute.

Locality.	Owner.	Diam.	Record.	Total Depth.	Reported by	Remarks.
Wildwood, ...	Wildwood Water Co.,.	6 in.,	....	347 feet, ...	Uriah White Estate,....	Finished with about 40 feet of strainer. Pumping capacity, about 200 gallons per minute.
Woodbine, ...	Land Improvement Co.,	......	....	125 feet, ...	Thos. B. Harper,.......	Water rose to within 12 ft. of surface. 40 gallons per minute when tested with 70-ft. pump.

OAKHURST (DEAL), MONMOUTH COUNTY.

Matthew Bros. report a well for William Kinney at Oakhurst (formerly Deal), which shows some interesting features. The record as reported by the contractors is as follows:

1. Grey sand,	140 ft.	0 to 140 ft.
2. Rock with many shells,	4 ft.	140 to 144 ft.
3. Fine white sand,	7 ft.	144 to 151 ft.
4. Marl or blue clay marl,	188 ft.	151 to 339 ft.
5. Grey sand,	34 ft.	339 to 373 ft.
6. Marl,	42 ft.	373 to 415 ft.
7. White sand,	7 ft.	415 to 422 ft.
8. Clay,	9 ft.	422 to 431 ft.
9. White sand (water),	66 ft.	431 to 497 ft.

The well yielded 150 gallons per minute, the water rising to within 12 feet of the surface.

It is not easy to correlate this record with the geological sections of Monmouth county as we know it from surface studies, owing to the abnormal thickness of the marl, No. 4 of the section. Nevertheless, if it be admitted that there is, perhaps, a mistake in identifying all the material between 151 and 339 feet as marl, it is possible to bring this record into close accord with other records from this region. In comparing this section with the regular stratigraphic column computations based upon the dip show that the base of the Lower Marl should be found at Oakhurst about 320 feet from the surface. This corresponds fairly closely with the base of No. 4 in the well section (339 feet), and gives us a clue to the probable correlation. The Lower Marl is about 30 feet thick, and is succeeded upward by the Red Bank sand, 115 feet, which is locally a black fine earthy sand, easily mistaken in a wellboring for true marl. Above the Red Bank sand is the Green Earth, 20 feet, also easily mistaken for true marl, and then the Middle Marl, 20 feet. Above the Middle Marl, and near the base of the Vincentown limestone, the next overlying layer, is a shell bed, the Terebratula Harlani bed, which would seem to agree with No. 2 of the well section. No. 6 of the well section (Marl, 42 feet) may very well be the clayey marl bed

which occurs as No. IV of the Clay Marl series. If these correlations are correct, the section would be referred as follows:

Grey sand,	140 ft.	Vincentown limesand and "yellow sand."	
Shell rock,	4 ft.		
Fine white sand,	7 ft.		
Marl or blue clay marl,	188 ft.	Middle Marl,	20 ft.
		"Green earth,"	20 ft.
		Red Bank sand,	115 ft.
		Lower Marl,	30 ft.
			185 ft.
Grey sand,	34 ft.	No. V of Clay Marl Series. (Wenonah sand.)	
Marl,	42 ft.	No. IV of Clay Marl Series. (Marshalltown marl.)	
White sand,	7 ft.	No. III of Clay Marl Series. (Columbus sand.)	
Clay,	9 ft.		
White sand,	66 ft.		

PART V.

The Mineral Industry. The Cement Industry.

By S. HARBERT HAMILTON.

Following the introduction at Trenton, in 1868, of the first Siemens-Martin open hearth furnace and the Bessemer process at other places, a still higher standard was demanded of iron ore. With the "chemical epoch" in ascendancy there was again a weeding out and only the fittest survived.

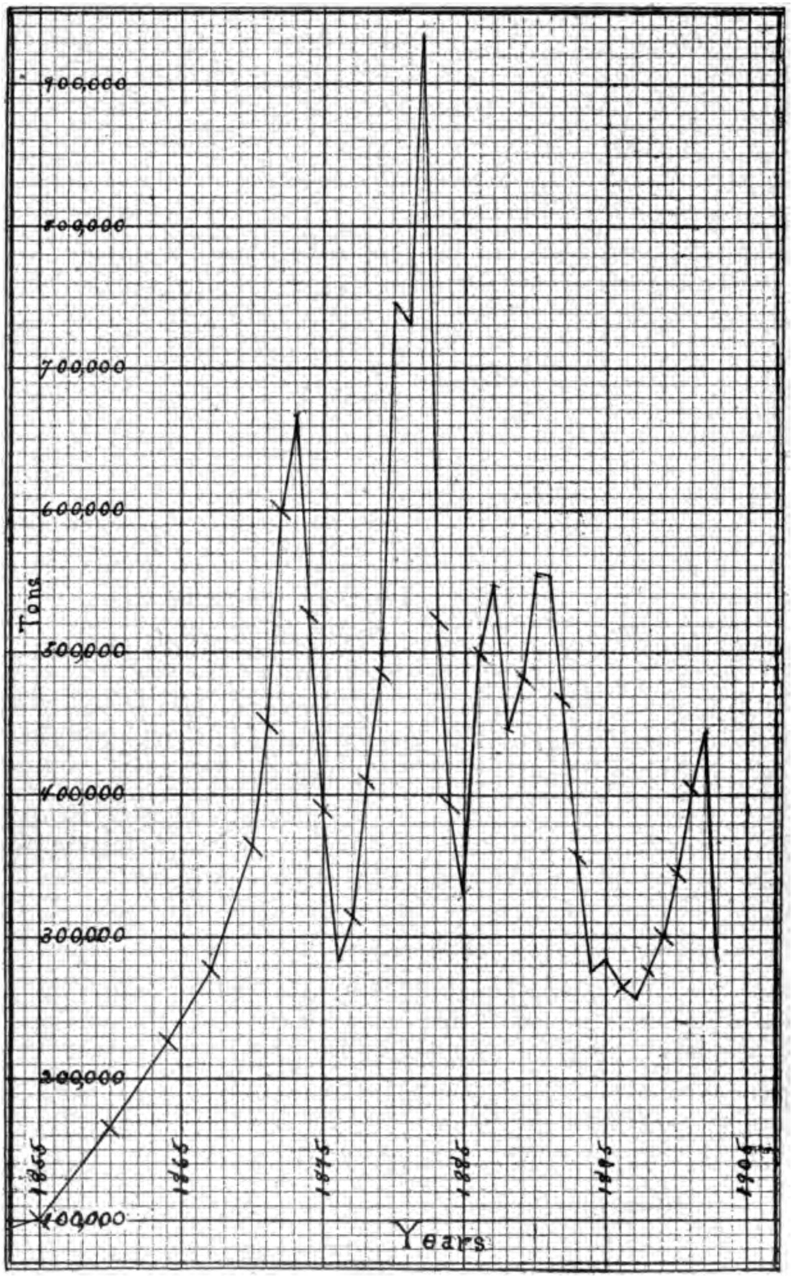
To-day the New Jersey iron-mining industry is in painful process of rejuvenation. The problem is not at the furnace (for there are no richer ores than the New Jersey magnetites), but at the mines. During the several decades that the best of New Jersey's mines have been operating, they have reached considerable depths. There is rich ore under Jersey still, but the problem is to get it out. The old shafts are crooked and narrow, mining has been carried on regardless of the future. When prices were good little of the profits were retained as permanent improvements on the properties. As a result of narrow, crooked workings and scattered boilers and machinery, a dull iron market and dear fuel closed many of the mines. Thus it is that New Jersey ores cannot compete with Lake and foreign ores—not because they are poor in iron, for they are not—but because the lower percentage ores can be mined so much more cheaply. The new era that is dawning in New Jersey is one of concentrated power plants, new straight shafts, electric separators and permanent improvements. The "ups and downs" of the iron-mining industry, since 1855, are graphically shown in Plate XIII.

The mines that are now in operation are run in direct connection with blast furnaces. The Hibernia mines ship their output to the Wharton and Andover furnaces. Oxford consumes its own ore. Richard ore goes to the Thomas furnaces, and the Ahlis ore is used in the Pequest stack. Hude ore is reduced at Stanhope.

THE OXFORD MINES, OXFORD FURNACE.

Empire Steel and Iron Company, Catasauqua, Pa., owners and operators; S. B. Patterson, General Manager; J. R. Wynn, Superintendent.

During the past year the work at these mines has been along the line of development only. The power plant noted in last



CURVE SHOWING THE IRON ORE PRODUCTION IN NEW JERSEY FROM 1855 TO 1904.

year's report having been completed, attention was turned to developing the mines so as to insure an increased and steady output.

At the Washington Mine the old shaft was so small and crooked and afforded such poor ventilation that another attempt to sink a new shaft was undertaken. Several previous attempts having been abortive, extra precautions were taken. This was finally successful and has resulted in a fine three-compartment shaft. The record is as follows:

From the surface down 60 feet is through glacial debris, 30 feet of this being "quicksand"; then through 65 feet of rock, at which distance the backing of ore 11 feet thick was struck. Through this backing and the old gunnies the shaft was timbered to the bottom of the mine, a distance of 229 feet. Next it was sunk 132 feet through the ore, making a total depth of 497 feet.

The Washington ore is a massive magnetite quite thoroughly impregnated with pyrite, so that the raw ore runs about five per cent. sulphur. This is considerably reduced by roasting, as the following recent analysis shows:

Silica,	10.18
Iron oxide,	82.22
Alumina,	1.90
Lime,	2.86
Magnesia,	.85
Sulphur dioxide,	.75
Phosphorus pentoxide,	.98
Manganese Oxide,	.14
Titanic oxide,	.17

This mine produced 30,172 tons during 1902.

McKinley Mine (formerly Oxford Slope 3).—The old shaft was so crooked and inadequate that in July, 1902, a new three-compartment shaft was started, which was completed by October of the same year. The first 60 feet penetrated soft, treacherous glacial debris. Here rock was encountered, which continued for 126 feet. The old workings were then struck and re-timbered for a distance of 379 feet, the shaft next being carried down through ore 50 feet, making its total length on the slope 615 feet. Stoping was done for some distance, but not much

ore was taken out. The vein dips about 56 degrees to the east, and trends north and south.

The analysis of this ore is:

Silica	14.84
Alumina,	2.04
Iron oxide,	70.78
Lime,	7.54
Magnesia,	2.98
Manganese,	.22
Phosphorus,	.28
Titanium,	.36
Sulphur,	.15

A portion of both these ores is used at the Oxford furnace mixer with about 10 per cent. of Lake ore to bring up the manganese content of the basic pig produced. The balance goes to the Pennsylvania furnaces of the company. The production in 1902 was 8,551 tons. Franklin "calcite" (crystalline limestone) is used at the Oxford furnace for flux.

THE BASIC IRON ORE COMPANY MINE.

The Basic Iron Ore Company, operators; R. L. Ahles, President; Erskine Hewitt, Secretary, Buttzville, N. J.

Active development work has been continued at this mine during the past year. No. 1 shaft is now 135 feet deep. Levels have been driven 460 feet west and 300 feet east on the vein. The eastern end of the level terminating at No. 2 shaft. Another shaft, No. 3, is now being sunk still farther to the east; it is now something over a hundred feet down, and it is planned to go some 250 feet before tunneling is commenced.

The plan for working this mine is a radical departure from methods heretofore used in New Jersey. The "caving" system, that of the Fayal mine in the Mesabi Range of Minnesota,* being used as a type. The shafts above mentioned are to go well to the bottom of the deposit. Levels are then drifted into the ore and timbered raises are sent to the top of the deposit. The ore

* See U. S. Geo. Sur. Mon. XLIII, p. 282.

is then blocked out in 28-foot parallelopipeds. Starting from the top a block is caved down to the main level and taken up the main shaft, and so on, always working from the top down. The overburden of glacial trash is then allowed to fall in, being kept from the ore by planking. This method saves an immense amount of timber, and allows of all the ore being removed. In this mine, with its heavy overburden of glacial debris and soft ore, this method can probably be worked to advantage.

The Ahles ore is markedly different in appearance from the greater proportion of the iron ore mined in New Jersey, which is compact magnetite with more or less pyrite through it. The ore from the Washington mine, which is near the Ahles mine, carries about 5 per cent. sulphur, which is removed by roasting. The Ahles ore contains practically no sulphur, and further differs from the Washington ore in a high water content, over 10 per cent., and is loosely pulverent. It is in reality a mixture of magnetite and limonite.

The occurrence of two such differently appearing ores in a restricted area, and with similar geological surroundings, may, perhaps, be explained by a chemico-geologic hypothesis. The Ahles body was, perhaps, originally a compact magnetite like other New Jersey ores, carrying a considerable percentage of sulphides. Possible dynamic movements allowed meteorologic waters to gain access to the ore where the dissolved oxygen reacted with the sulphides, changing them to soluble sulphates and limonite. It is probable that the surface waters on their way through the ore deposited the manganese noted in the analysis.

The following analysis furnished by the producers, illustrate the possible alterations and hydration.

	Washington.	*Ahles.*
Silica,	10.18	10.72
Iron,	59.54	46.
Sulphur,	4.	nil.
Manganese,	.07	4.
Phosphorus,	.43	nil.
Titanium,	.10	nil.
Combined water,	nil.	10 to 12.

During the past year the only ore taken from these mines has been that removed in the process of development. This has

amounted to some 30,000 tons, of which 20,605 tons 12 cwt. were used in the Pequest furnace, mixed with the ore from Ringwood, N. J. It produced a high-grade pig.

HUDE MINE, STANHOPE, N. J.

Musconetcong Iron Works, Elizabethport, N. J., lessees; John S. Kennedy, Stanhope, Manager.

These mines continue to be worked steadily in a small way. The ore occurs in irregular lenses in hornblendic gangue, from which it is readily cobbed by hand. As noted in the Annual Report for 1901, molybdenite is found disseminated through the ore, and is frequently found altered to canary-yellow and orange coatings of molybdite and possibly ilsemannite. The hornblende where exposed to the weather has altered to a golden vermiculite, which might be referred to the vermiculite derived from hornblende, and described by Lewis* as philadelphite. The ore, like that at Oxford Furnace, is a close-grained magnetite with massive pyrite through it. The magnetite is often found here with slickensided surfaces, so that it resembles a natural mirror. Such a specimen, weighing about 150 pounds, is in the State Museum at Trenton.

During the past year about 9,000 tons of ore were hauled some one and one-half miles by team to the Stanhope furnace, where it is mixed with Lake and Cuban ore and made into a high-grade foundry pig. The slag from this furnace is consumed by the United States Mineral Wool Company, whose plant adjoins the furnace.

IRONDALE MINES, WHARTON (PORT ORAM), N. J.

New Jersey Iron Mining Company, 72 Elliott street, Dover, owners; Peter Penaluna, manager.

During the past year nothing has been done in the Sterling mine, operations being confined to the Hurd slope.

* Pro. Acad. Nat. Sci. Phila., 1877, p. 269.

Two new sinks, each 60 feet, have been put down during the past year. Stoping has been continued east on a six-foot vein 57 feet high. Stope No. 5, West, has a five-foot vein, and has been stoped 57 feet also. Stope No. 4, West, shows a seven-foot vein, and has been stoped to a height of 45 feet. The present total depth of the mine on the incline is 1,070 feet.

The output of this mine is sold on the open market, and goes principally to the furnaces of Pennsylvania.

During the past year about 15,000 tons have been produced.

THE RICHARD MINE, MT. PLEASANT.

The Thomas Iron Company, B. F. Fackenthal, Jr., President, Easton, Pa., owners; James Arthur, Superintendent, Wharton, N. J.

During the past year a new central-power plant has been installed at these mines, consisting of two new Harrisburg automatic engines of 200 horse-power each, direct connected to 150 K. W. General Electric generators. The power is to be conveyed to shafts No. 4, No. 5 and No. 6, each of which is furnished with new Ledgewood electric hoists of 80 horse-power each. Any surplus power will be utilized for crushing and pumpage.

No. 2 shaft has been abandoned, and is at present being actively "robbed" before permanently closing.

No. 5 shaft is now 875 feet below the surface, and has been worked 400 feet to the southwest, which brings the present workings nearly under the old No. 2 shaft. From No. 5 shaft work has been pushed northeast about 100 feet, where there is a 25-foot breast of ore. Operations are at present suspended in this drift owing to the danger of tapping a large body of water in the old workings. However, two new air-lift pumps, each capable of raising 1,000,000 gallons 1,000 feet in twenty-four hours, are being installed, and as soon as they are running, work will be pushed.

Operations during the past year have been confined to the Mt. Pleasant vein, which dips 52° to the southeast. No. 4 shaft cuts the vein at 900 feet, where it is six to ten feet in width. No.

5 shaft penetrated it at 500 feet, where it is five to fifteen feet wide. No. 6 shaft again at 900 feet, where the width varies from five to fifteen feet.

From January, 1902, to January, 1903, 100,656 tons 2 cwt. was mined.

TEABO MINE, MOUNT HOPE, N. J.

Joseph Wharton, owner; Edward Kelly, manager.

The new shaft mentioned in last year's report was continued to 300 feet, mostly through the old workings. At a depth of 60 feet good ore was encountered and again at 200 feet. The shaft now terminates in rock, but it is expected that another shoot of ore will shortly be found. Work has been suspended at this mine awaiting more favorable conditions in the iron market.

MOUNT HOPE MINES, MOUNT HOPE, NEW JERSEY.

Empire Steel and Iron Company, Catasauqua, Pa., owners and operators; S. B. Patterson, General Manager; Duke Peckitt, Superintendent.

Both the Taylor and Elizabeth mines have been kept working to some extent during the past year. Both mines have reached bed rock in the southwest portions.

In the Elizabeth mine a hole was bored with a diamond drill 505 feet in the foot wall but no ore was found.

No work has been done at the Hickory Hill mines for many years.

The total output for 1902 was:

Taylor mine,	5,835 tons.
Elizabeth mine,	14,619 tons.

BEACH GLEN MINE, BEACH GLEN, N. J.

Benjamin Nicoll, 59 Wall street, New York City, owner.

The double skip-way shaft* was continued to 517 feet. At

* Rept. 1901, p. 144.

475 feet a rich vein, 14 feet wide, was encountered. This was worked about 50 feet on each side of the shaft in a northeasterly and southwesterly direction, and about 7,000 tons of ore removed. The ore runs 56 to 60 per cent. iron, low in sulphur, 0.003 to 0.009 phosphorus and no titanium. This mine is now closed but with higher prices in the iron market will be reopened.

HIBERNIA MINES, HIBERNIA, N. J.

Joseph Wharton, Philadelphia, owner; Edward Kelly, Manager, Wharton (Port Oram), N. J.

The Andover Mine (formerly Lower Wood, Crane and Church mine). This mine has been sunk from the 23 to the 24 level, a distance of about 45 feet, and has been worked southwest to the "lean ground." A drift was driven through this lean ground 62 feet, at which point a body of ore was encountered 8 feet in width. The miners then raised and formed a stope. Twenty-four level has been worked to De Camp line, a distance of about 800 feet.

This mine is now some 1,200 feet below the surface or about 600 feet below sea level. The total amount of ore raised was 40,185 tons 9 cwt. in 1902.

De Camp Mine. The skip-way in this mine has been extended about 100 feet farther, making it in all about 600 feet. During the year 1902 about 11,000 tons were taken from this mine.

Upper Wood Mine. Number six level of this mine has been stoped to the southwest, a distance of about 650 feet or nearly underneath De Camp shaft No. 4. In a northeasterly direction the stope of No. 6 level has been driven about 500 feet to the Wharton line. The sink in the Upper Wood has been continued to No. 8 level, which has been worked southwest 300 feet and northeast 560 feet to the Wharton line. The shaft was then further continued to No. 9 level about 60 feet.

The Wharton Mine has now a total depth of 1,500 feet from the surface or nearly 600 feet below tide. It has the same number of stopes as mentioned in the last report but the installation of new machinery has facilitated the work greatly.

During the past year at No. 9 shaft a similar cobber and separator to that in use at shaft 11, has been installed and gives entire satisfaction.

In No. 12 (prospect) shaft the pitch has been changed from 37° to 76° southeast. It has been sunk to 680 feet, at which point a cross cut in the foot wall revealed a vein 7 feet in width.

The total production of the Wharton mine was 97,596 tons, 6 cwt., during the past year, 1902.

The Magnetic Separator at the foot of the hill has been in continuous operation with good results during the past year, 11,562 tons, 11 cwt., of concentrates having been shipped.

The material coming to the separator is magnetite intimately mixed with hornblende and feldspar,* carrying from 22 per cent. to 30 per cent. metallic iron. It is first crushed to about 2-inch cubes, when it is passed to the magnetic cobber and all particles containing iron are picked up and passed to the fine crushing rolls, which reduces it to ¼-inch mesh, after which it is passed to the magnetic separator. After separation the heads run from 58 per cent. to 62 per cent. metallic iron, and the tails from 8 per cent. to 11 per cent. With hand cobbing 15 to 30 per cent. iron is found in the tailings. A further advantage of the Wharton separator is that the cobber tails (2½ inches in diameter), and the concentrator tails (sand), are salable at from $0.75 to $1.00 a ton.

PETERS MINE, RINGWOOD, PASSAIC CO., N. J.

Cooper, Hewitt & Co., owners; Frank L. Nason, consulting engineer, in charge.

Mr. Nason reports that during the year 1903 the new shaft has been completed to a depth of 265 feet. In sinking this shaft three new ore shoots were passed through. Number 4 shoot, 40 feet high by 16 feet wide, and two others, each 16 feet high by 10 feet wide. The ore in these three shoots is very high grade, over 65 per cent. Fe., but they are too small to work

* See An. Rept., 1890, p. 72, for account of rocks associated with the iron ores.

independently. In the hanging wall of No. 2 are shoot, at the bottom of the shaft, a new ore shoot was struck 8 feet in. At the point of cutting, the shoot was 8 feet thick, and the ore will probably run 65 to 68 per cent. iron. This shoot is being developed with the idea of determining its size.

During the summer of 1903 the water in the open cut was pumped out. This was done for two reasons. First, no surveys of the old Peters workings are extant, and it was not deemed safe to work in the shaft, only 100 feet distant, with this large body of water an unknown distance through possible drifts from the shaft.

Second, in case development warranted, it is planned to put down a permanent incline through the open cut and on No. 2 slope, so that ores from No. 2, No. 3 and No. 4 ore shoots can be raised with only one handling.

Since November 1st, a ladderway has been installed in the shaft, so that miners can have ingress and egress to the workings. A pump 12 x 16 x 12 feet has also been sunk at the foot of the shaft, a pump station has been cut out, a large pump installed and pipe and steam lines placed. This will enable pumps to deliver water to the surface with a single column.

It is also intended to come up on the slope of No. 2 ore shoot to the open cut, and to take the water there to the shaft and from there to the surface.

No ore is being shipped from the mine now. No ore is being broken except what is necessitated in pushing development work. This development work is being carried on and will be until such time as an ore reserve is opened up, sufficient to insure mining for one year. When this work is completed, the mine will be closed unless the market for iron ore brightens.

A 150 horse-power boiler, a large Ingersoll-Sargent air compressor and four large pumps have been added to the plant during 1903.

THE THATCHER HEMATITE MINE.

The Thatcher mine, between New Village and Stewartsville, is being pumped and otherwise made ready for work. The ore is hematite of excellent quality, it is said.

The Zinc Mines.

James B. Tonking, Superintendent of the New Jersey Zinc Company's mines at Franklin Furnace, has kindly furnished the following notes regarding their operations during the year. It is gratifying to observe the steady increase in the production of these mines during the last few years.

Throughout the whole year the work of development has been prosecuted for the purpose of still farther blocking out the ore body. The usual irregularities in the country rock formation, causing the walls to bend in and out both on strike and dip, have continued, and the usual variations of lean and rich ore have been passed through, together with masses of garnet and rock intrusions here and there.

The developments in the Parker mine, which represents the northeasterly end of the deposit, have been of interest, owing to the installation of a diamond drill for the purpose of exploring below the lowest point in the deposit and in an easterly direction. Nothing was found in either direction indicating any new ore bodies.

In the Taylor mine, which represents the southwesterly end of the deposit, the work of most interest was that of extending a raise from the 700-foot level in the direction of Trotter mine No. 4 shaft, and the turning off from this raise the 50-foot levels as elevation for each one was reached. During the coming year it is anticipated that connection will be completed, giving these mines a third outlet, which is always desirable in a property of this kind.

The open work was continued through a large portion of the year. A considerable quantity of the ore in the direction of the large dike on the west leg above the old tunnel level was removed. Nothing was done below the tunnel level in this connection.

The total product mined for the year was 279,419.03 gross tons, a gain of 70,033 tons over 1902.

The Trotter mine at Franklin Furnace, N. J., and the Stirling Hill mines at Ogdensburg, New Jersey, were inactive throughout the year.

Copper Mining.

The New Jersey copper mines and minerals noted in previous Annual Reports have been steadily kept in view during the past year by the various groups of business men. At present New Jersey does not contribute to the world's copper supply, although there is some prospect of copper being produced in New Jersey shortly.

The following notes have been obtained from owners of the mines mentioned:

AMERICAN COPPER MINE, SOMERVILLE, N. J.

The following details of work at this mine during the last two years have been furnished by Josiah Bond, General Manager, with the permission of J. C. Reiff, President.

The main incline shaft has been sunk from 1,110 to 1,240 feet, and some work was done in the drifts to the amount of 240 feet, making the mine a total of 1,400 feet slope and 2,040 feet of side drifts, not including portions of the old work.

The showing made by this new work, all in the deeper part of the mine has been the most encouraging. The values are now practically all in native copper, other forms being confined to joint faces, etc., along which percolating waters have had readiest passage, and constitute only about one-quarter of one per cent. of the whole. As indicated in the last report the copper has increased in size, pieces weighing one-half to three-quarters of a pound in weight having been found. The ore nodules have increased in size and in copper content, one mass of large size running 30 per cent. copper.

In order to relieve the pumps during heavy rains by drawing away the surface waters where they run down through the broken trap near the outcrop, a drainage tunnel, starting at a point 130 feet down the main slope and draining a vertical depth of 24 feet, has been completed through the red shales beneath the trap. It has proved a very successful economy, handling at flood times as much as 125 gallons of water per minute, all of which formerly had to be pumped. In driving it copper was encountered about

Portland Cement Industry.

The New Jersey Portland cement industry is in every way in a most flourishing condition. Practical experience of the manufacturers has confirmed the studies of the State Geological Survey, that there is a practically inexhaustible supply of excellent cement rock in this State.

New Jersey still holds second rank as a producer of Portland cement, being exceeded only by Pennsylvania. Furthermore, New Jersey cement brings as high a price as any cement in the open market—a practical demonstration of the excellency of the natural rock and the skillful, scientific and technical treatment accorded it by the manufacturers. The works are all administered in the utmost progressive spirit, all manner of labor-saving machinery being in use and everything planned, so that a hand scarcely touches the material from the quarry to the car of shipment.

A prominent feature of the current year is the putting in operation of the huge Edison plant, at New Village, the lamentable explosion in the coal pulverizing plant having necessitated extensive alterations and delays. This plant is a radical departure in cement manufacture, and the results of this huge automaton will be watched with interest by the whole technical world.

So far no new plants have been begun in New Jersey, and it is well that a certain amount of caution is exhibited.* The care not having to be with lack of raw material, but rather with the danger of over production.

THE ALPHA PORTLAND CEMENT COMPANY.

Works at Alpha, N. J. (Lehigh Valley R. R.); office, First National Bank Building, Easton, Pa.

In 1891 Thos. D. Whitaker commenced the manufacture of Portland Cement on advice and information furnished by the

* See "Stone," N. Y., Vol. XXVI, No. 4, p. 343.

QUARRY AND WORKS OF THE ALPHA PORTLAND CEMENT COMPANY.

New Jersey Geological Survey. In 1895 the present operators purchased the plant, which then had a capacity of from 500 to 700 barrels per day. The rock at Alpha produced such an excellent cement that the plant was gradually increased until in 1900 there were ten kilns with a capacity approximating 2,000 barrels per day. In 1901 a new mill of the same capacity was erected; the former being known as Mill No. 1 and the latter as Mill No. 2. In the summer of 1903 four more kilns were added to Mill No. 2, making 14 kilns for this plant. This company is now manufacturing at Alpha about five thousand barrels daily. Since the Survey's report of the Portland Cement industry in 1900, in which the distribution of the cement rock was delineated, the company has increased its holdings from 40 acres to 200 acres. The quantity of cement manufactured by this company since its inception is, in round numbers, 6,000,000 barrels.

A boring made by the company showed the rock to extend 325 feet from the surface.

1894,	100,000	barrels.
1895,	120,000	"
1896,	215,000	"
1897,	325,000	"
1898,	350,000	"
1899,	380,000	"
1900,	500,000	"
1901,	830,000	"
1902,	1,180,000	"
1903,	1,400,000	"

The rock used at Alpha is a soft, friable argillaceous slate or shale, which is referred to the Trenton epoch. The strata dips steeply to the south. Its upturned edges are irregularly eroded and overlaid by from four to ten feet of heavy yellow clay. Percolating surface waters, of course, have found easy access to the almost perpendicular strata, and on their downward way have removed the calcium carbonates as bicarbonate by means of the carbonic acid in them, $H_2CO_3 + CaCO_3 = H_2Ca\ (CO_3)_2$. Farther down, with increased pressure, the calcium carbonate has been re-deposited as normal crystallized calcium carbonate or calcite. Large masses of this mineral with rhombohedral cleavages

two or three inches on the faces are found, as well as rounded scalenohedrons thickly studding fissures and lining cavities with mammalary crystalline surfaces. These last-mentioned crystals with their confused groupings are often covered with a thin film, giving them an amberoid appearance, with the iridescent sheen of an oily film on water.

The upper portions of the shale are not only poorer in lime, and, consequently more aluminous than the lower sections of the same strata, but are white and free from carbon, while the same layer as it increases in depth also increases in color, passing through leaden gray almost into a black graphitic slate. It seems reasonable to assume that percolating meteorologic water carried considerable dissolved oxygen with it. That as the water worked downward through the upturned rock the dissolved oxygen reacted with the carbonaceous matter in the rock thus:

$$n\,H_2O_2 + C = CO_2 + n\,H_2O.$$
$$CO_2 + H_2O = H_2CO_3.$$

and that the carbonic acid (H_2CO_3) reacting with the calcium carbonate content of the shale formed, as before indicated, bicalcium carbonate, which in lower levels was again precipitated as the normal salt in the form of calcite.

The method of quarrying at the Alpha is to drill across the strata with steam drills and break down the rock with dynamite, and load it on mine cars with a steam shovel. These cars are then hauled up an inclined railroad by a cable. Four tracks are in use at Alpha, two for each mill. In practice it is found necessary to bring up the lime content by the addition of limestone (so-called calcite) imported from Pennsylvania. The exact ratio of "calcite" to cement rock is determined by chemical analysis and calculation continuously, a number of chemists being employed. The proper blend of "calcite" and "cement rock"* is dumped into Gates crushers and reduced to less than an inch. The crushed "blende" is next dried in continuous rotary dryers. After drying

* For a brief outline of the chemistry of cement see Annual Report of the State Geologist for 1900 or further in "The Cement Industry" reprinted from Engineering Record, N. Y., 1900.

it is ground in tube and ball mills and then fed to the continuous rotary kilns of the conventional type, using pulverized coal with air under pressure as fuel. The constant flow of "clinker" (as the burned mass is called), is partially quenched as it passes in the link belt conveyor to the cooling towers. The product is finally ground to an impalpable powder in Griffin mills and allowed to "age" in ample warehouses. The whole works are equipped with automatic conveyors of the screw and link belt type, and a hand rarely touches the material from quarry to warehouse.

THE VULCANITE PORTLAND CEMENT COMPANY.

Works at Vulcanite, N. J. (Central R. R. of N. J.); office, Real Estate Trust Building, Philadelphia, Pa.

In 1894 the directorate of the Vulcanite Paving Co. of Philadelphia, in order to be assured of an adequate supply of first quality cement to use in their paving contracts, commenced the erection of a plant close to the Alpha works. The original mill* had 5 rotary kilns. Later No. 2 mill, with 6 kilns, was erected. Finally an additional factory of 10 more kilns was installed. Since the report on the Portland Cement Industry, 1900, the company has increased its holdings of cement rock land from 205 to 250 acres.

The output to date is given as follows:

	BARRELS.
1895 (6 Mos.),	14,000
1896,	60,000
1897,	125,000
1898,	218,000
1899,	513,000
1900,	690,000
1901,	725,000
1902,	975,000
1903,	1,460,000

* Plant described in "The Cement Industry," New York, N. Y., 1900, p. 94. Also see handsome brochure issued by the company, no date.

The rock of the Vulcanite quarries as pointed out in 1900 by Dr. Kümmel* (where analyses are given which are similar to these to-day) is like that at Alpha. However, the same chemical changes due to percolating meteorologic waters have not taken place on so extensive a scale as at Alpha. The planes of slaty cleavage are not so open, and the rock is firmer and less altered. No calcite was found deposited as crystals, although in the eroded uptorn portions of the rock, which had been stripped of residuary clay, remains of what Dr. Kümmel considered crinoids were observed.

Two quarries, utterly independent of each other, are operated as pits. The rock, broken down by dynamite, is hoisted and conveyed by wire cable tramways to the mills. Two independent cableways are operated at each pit.

THE EDISON PORTLAND CEMENT COMPANY.

Works at New Village, D., L. & W. R. R.; office, Girard Building, Philadelphia.

The plant mentioned in this annual for 1900† was put in operation in October of this year, and to date has made about 80,000 barrels.

The quarries are some two miles from the works and are connected therewith by a standard gauge railroad. Both "cement rock" and limestone occur in close proximity. The rock in a general way resembles that of the quarries already mentioned, although of course the excavations are not nearly so extensive as yet. A rather radical departure from quarrying methods is being inaugurated in the form of a movable roof over each quarry. This is of corrugated iron on light steel frames resting on wheels which in turn run on a T-rail track. By thus covering the quarry it is intended to work it in all weathers, the roof being moved as quarrying proceeds. After being blown down the rock is loaded into cars with steam shovels.

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* Loc. Cit., pp. 22 and 43.

† P. 29.

The mill is a radical departure from most cement mills. The rock is dumped on a train of corrugated rolls, the first pair being five feet wide by five feet in diameter. The other two pair in the series are three feet wide with corrugations decreasing in width. A rock weighing five or six tons will be reduced to one-half inch and less by this treatment.

A belt conveyor takes the crushed rock to a dryer, which is a tower heated from a furnace at the bottom. The crushed rock, entering the top of the tower, is allowed to fall on a series of opposite plates having a reciprocating motion; the material in its downward course is alternately held and dumped from plate to plate. Reaching the bottom of the drying tower, the now steaming rock is taken by conveyor to the rock stock house, which is maintained at a high temperature, and exhausted with a fan. On its way thither the "crush" is automatically sampled for chemical analysis. From the rock store house the crushed rock is conveyed by link belt as needed to the weighing and mixing house where the amount of limestone required to bring up the calcium content, as determined by analysis and calculation, is added. The blended rocks are automatically conveyed to the "chalk grinding house," where, by passing them through rolls, the half-inch "blende" is partially reduced to an impalpable powder.

Another radical departure is the treatment accorded the ground "chalk" when it reaches "blower house, No. 1," by belt conveyor from the grinding house. Here by means of air blasts the very finely divided material is blown from the coarser particles which are returned automatically to the grinders. The fine chalk is stored until required at the kilns. So far two kilns only have been installed and one only is in operation. They are of extraordinary construction, being 9 feet in diameter and 150 feet long. (The usual practice is not to use rotary kilns over 60 feet long.) The finely ground coal used in a blast of compressed air as fuel in the kilns, was formerly ground and winnowed as described in the treatment of the "chalk," but a lamentable explosion occurred in this department when the plant was first put in operation by the sparking of an electric motor igniting the explosive mixture of air and coal dust. At present

the coal is ground in ball and tube mills. As the clinker leaves the kiln proper it passes through a revolving drum which serves to partially cool it. It is then received by a bucket and chain conveyor, slightly quenched and passed on to the clinker store house from whence it is drawn as required to the "clinker grinding house." This contains two sets of fine grinding rolls. The material issuing from these rolls is separated by winnowing in "blower house, No. 2," just as is done in the "chalk" grinding house and the material that has not been sufficiently reduced is returned to be re-ground. It is stated that 85 per cent. of the finished product will pass through a two hundred mesh screen.

The bagging and barreling is all done automatically, and we are informed that so automatic is the plant in every respect that only six more men are required to increase the output of from 1,200 to 2,500 barrels per day.

Mineral Statistics

For the Year 1903.

IRON ORE.

The total production of the mines, as reported by the several mining companies, was 289,323 tons.

The table of statistics is reprinted, with the total amount for 1903 added.

TABLE OF STATISTICS.

Year.	*Iron Ore.*	*Authority.*
1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.
1864	226,000 tons	Annual Report State Geologist.
1867	275,067 tons	" " "
1870	362,636 tons	U. S. census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons*	" " "
1877	315,000 tons*	" " "
1878	409,674 tons	" " "
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "
1885	330,000 tons	" " "
1886	500,501 tons	" " "
1887	547,889 tons	" " "
1888	447,738 tons	" " "

* From statistics collected later.

Year.	Iron Ore.	Authority.
1889	482,109 tons	Annual Report State Geologist.
1890	552,996 tons	" " "
1891	551,358 tons	" " "
1892	465,455 tons	" " "
1893	356,150 tons	" " "
1894	277,483 tons	" " "
1895	282,433 tons	" " "
1896	264,999 tons	" " "
1897	257,235 tons	" " "
1898	275,378 tons	" " "
1899	300,757 tons	" " "
1900	342,390 tons*	" " "
1901	401,151 tons	" " "
1902	443,728 tons	" " "
1903	289,323 tons	" " "

* The figures, 407,596 tons, given in the report for 1900, included 75,206 tons of crude material which should have been reduced to its equivalent in concentrates.

ZINC ORE.

The production of the New Jersey Zinc Company's mines is reported by Mr. James B. Tonking, Superintendent, to be 279,419 gross tons of zinc and franklinite ore. It was chiefly separated at the company's mills. This report shows a gain in production over 1902 of 70,033 tons.

The statistics for a period of years are reprinted from the last annual report.

ZINC ORE.

Year.	Zinc Ore.	Authority.
1868	25,000 tons†	Annual Report State Geologist.
1871	22,000 tons†	" " "
1873	17,500 tons	" " "
1874	13,500 tons	" " "
1878	14,467 tons	" " "
1879	21,937 tons	" " "
1880	28,311 tons	" " "
1881	49,178 tons	" " "
1882	40,138 tons	" " "
1883	56,085 tons	" " "

†Estimated for 1868 and 1871. Statistics for 1873-1890, inclusive, are for shipments by railway companies. The later reports are from zinc-mining companies.

Year.	*Zinc Ore.*	*Authority.*
1884	40,094 tons	Annual Report State Geologist.
1885	38,526 tons	" " "
1886	43,877 tons	" " "
1887	50,220 tons	" " "
1888	46,377 tons	" " "
1889	56,154 tons	" " "
1890	49,618 tons	" " "
1891	76,032 tons	" " "
1892	77,298 tons	" " "
1893	55,852 tons	" " "
1894	59,382 tons	" " "
1895*		
1896	78,080 tons	" " "
1897	76,973 tons	" " "
1898	99,419 tons	" " "
1899	154,447 tons	" " "
1900	194,881 tons	" " "
1901	191,221 tons	" " "
1902	209,386 tons	" " "
1903	279,419 tons	" " "

* No statistics were published in the Annual Report for 1895.

order to secure prompt attention requests for both reports and maps should be addressed simply "State Geologist," Trenton, N. J.

CATALOGUE OF PUBLICATIONS.

GEOLOGY OF NEW JERSEY. Newark, 1868, 8vo., xxiv + 899 pp. Out of print.

PORTFOLIO OF MAPS accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.
2. Triassic formation, including the red sandstone and trap-rocks of Central New Jersey; colored. Scale, 2 miles to an inch.
3. Cretaceous formation, including the greensand-marl beds; colored. Scale, 2 miles to an inch.
4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.
5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.
6. Map of the Ringwood iron mines; printed in two colors. Scale, 8 inches to 1 mile.
7. Map of Oxford Furnace iron-ore veins; colored. Scale, 8 inches to 1 mile.
8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile.

A few copies are undistributed.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for firebrick, pottery, etc. Trenton, 1878, 8vo., viii + 381 pp., with map.

A PRELIMINARY CATALOGUE of the Flora of New Jersey, compiled by N. L. Britton, Ph.D. New Brunswick, 1881, 8vo., xi + 233 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi + 439 pp. Very scarce.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part I. Mineralogy. Botany. Trenton, 1889, 8vo., x + 642 pp. (Postage, 25 cents.)

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton. 1890, 8vo., x + 824 pp. (Postage, 30 cents.)

REPORT ON WATER-SUPPLY. Vol. III of the Final Reports of the State Geologist. Trenton, 1894, 8vo., xvi + 352 and 96 pp. (Postage, 21 cents.)

REPORT ON THE PHYSICAL GEOGRAPHY of New Jersey. Vol. IV of the Final Reports of the State Geologist. Trenton, 1898, 8vo., xvi + 170 + 200 pp. (Scarce.)

REPORT ON THE GLACIAL GEOLOGY of New Jersey. Vol. V of the Final Reports of the State Geologist. Trenton, 1902, 8vo., xxvii + 802 pp. (Sent by express, 35 cents if prepaid, or charges collect.)

BRACHIOPODA AND LAMELLIBANCHIATA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates XXXV and Map. (Paleontology, Vol. I.) (By express.)

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1892, quarto, pp. 402, plates L. (Paleontology, Vol. II.) (By express.)

PALEOZOIC PALEONTOLOGY. Trenton, 1903, 8vo., xii + 462 pp., plates LIII. (Paleontology, Vol. III.) (Postage, 20 cents.)

ATLAS OF NEW JERSEY. The complete work is made up of twenty sheets, each about 27 by 37 inches, including margin. Seventeen sheets are on a scale of 1 inch per mile and three on a scale of 5 miles per inch. It is the purpose of the Survey gradually to replace Sheets 1-17 by a new series of maps, upon the same scale, but somewhat differently arranged so as not to overlap. The new sheets will be numbered from 21-37, and will be subject to extensive revision before publication. These sheets will each cover the same territory as eight of the large maps, on a scale of 2,000 feet per inch. Nos. 2, 4, 5, 7, 11 and 12 have already been replaced as explained below.

No. 1. Kittatinny Valley and Mountain, from Hope to the State line.

No. 3. Central Highlands, including all of Morris county west of Boonton, and Sussex south and east of Newton.

No. 6. The Valley of the Passaic, with the country eastward to Newark and southward to the Raritan river.

No. 8. Vicinity of Trenton, from New Brunswick to Bordentown.

No. 9. Monmouth Shore, with the interior from Metuchen to Lakewood.

No. 10. Vicinity of Salem, from Swedesboro and Bridgeton westward to the Delaware.

No. 13. Vicinity of Barnegat Bay, with the greater part of Ocean county.

No. 14. Vicinity of Bridgeton, from Allowaystown and Vineland southward to the Delaware bay shore.

No. 15. Southern Interior, the country lying between Atco, Millville and Egg Harbor City.

No. 16. Egg Harbor and Vicinity, including the Atlantic shore from Barnegat to Great Egg Harbor.

No. 17. Cape May, with the country westward to Maurice river.

No. 18. New Jersey State Map. Scale, 5 miles to the inch. Geographic.

No. 19. New Jersey Relief Map. Scale, 5 miles to the inch. Hypsometric.

No. 20. New Jersey Geological Map. Scale, 5 miles to the inch. (Out of print.)

No. 22. Eastern Sussex and Western Passaic counties. Replaces Sheet 4.

No. 24. Southern Warren, Northern Hunterdon and Western Morris counties. Replaces Sheet 2.

No. 26. Vicinity of Newark and Jersey City—Paterson to Perth Amboy. Replaces in part Sheet 7.

No. 27. Vicinity of Trenton—Raven Rock to Palmyra, with inset, Trenton to Princeton. Replaces Sheet 5.

No. 31. Vicinity of Camden, to Mount Holly, Hammonton and Elmer. Replaces Sheet 11. (Ready in February or March.)

No. 32. Part of Burlington and Ocean counties, from Pemberton and Whitings to Egg Harbor City and Tuckerton. Replaces Sheet 12. (Ready in February or March.)

Other sheets of the new series, Nos. 21–37, will be printed from time to time, as the older sheets become out of print. All the maps are sold at the uniform price of twenty-five cents per sheet, either singly or in lots. Since the Survey cannot open small accounts, and the charge is merely nominal, remittance should be made with the order. Order *by number* of the State Geologist, Trenton, N. J.

TOPOGRAPHIC MAPS, NEW SERIES.

These Maps are the result of recent surveys, and contain practically all of the features of the one-inch scale maps, with much new material. They are published on a scale of 2,000 feet to an inch, and the sheets measure 26 by 34 inches. The Paterson, Hackensack, Morristown, Newark, Jersey City, Plainfield, Elizabeth, New York Bay, Amboy, Navesink, Long Branch, Shark River, Trenton East, Camden, Mount Holly, Woodbury, Taunton, and Atlantic City Sheets have been published and are now on sale. The price is twenty-five cents per sheet, *payable in advance*. Order *by name* any of the sheets above indicated as ready, of The State Geologist, Trenton, New Jersey.

ANNUAL REPORTS.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo., 24 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1865. Trenton, 1866, 8vo., 12 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, on the Geological Survey of New Jersey, for the year 1866. Trenton, 1867, 8vo. 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year of 1867. Trenton, 1868, 8vo., 28 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1869. Trenton, 1870, 8vo., 57 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps. Very scarce.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1872. Trenton, 1872, 8vo., 44 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1873. Trenton, 1874, 8vo., 128 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1874. Trenton, 1874, 8vo., 115 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1875. Trenton, 1875, 8vo., 41 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1876. Trenton, 1876, 8vo., 56 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1877. Trenton, 1877, 8vo., 55 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1878. Trenton, 1878, 8vo., 131 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1879. Trenton, 1879, 8vo., 199 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1880. Trenton, 1880, 8vo., 220 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1881. Trenton, 1881, 8vo., 87+107+xiv. pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1882. Camden, 1882, 8vo., 191 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp. Scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8vo., 254 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo., 45 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo., 87 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo., 112 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1890. Trenton, 1891, 8vo., 305 pp., with maps. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1891. Trenton, 1892, 8vo., xii+270 pp., with maps. (Postage, 10 cents.) Scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1892. Trenton, 1893, 8vo., x+368 pp., with maps. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x+452 pp., with maps. (Postage, 18 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo., x+304 pp., with geological map. (Postage, 11 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1895. Trenton, 1896, 8vo., xl+198 pp., with geological map. (Postage 8 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1896. Trenton, 1897, 8vo., xxviii+377 pp., with map of Hackensack meadows. (Postage, 15 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1897. Trenton, 1898, 8vo., xl+368 pp. (Postage, 12 cents.)

ANNUAL REPORT of the State Geologist for 1898. Trenton, 1899, 8vo., xxxii+244 pp., with Appendix, 102 pp. (Postage, 14 cents.)

ANNUAL REPORT of the State Geologist for 1899 and REPORT ON FORESTS. Trenton, 1900, 2 vols. 8vo., Annual Report, xliii+192 pp. FORESTS, xvi+327 pp., with seven maps in a roll. (Postage, 8 and 22 cents.)

ANNUAL REPORT of the State Geologist for 1900. Trenton, 1901, 8vo., xl+231 pp. (Postage, 10 cents.)

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* These reports can be supplied only to libraries.

ANNUAL REPORT of the State Geologist for 1901. Trenton, 1902, 8vo., xxviii+178 pp., with one map in pocket. (Postage, 8 cents.)

ANNUAL REPORT of the State Geologist for 1902. Trenton, 1903, 8vo., viii+155 pp. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist for 1903.

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